Volume II

Appendix J

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Oil Spill Modelling Report

TEXAS GULFLINK PROJECT: OIL SPILL MODELING REPORT

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BACKGROUND

INTRODUCTION AND SCOPE

The intent of this document is to determine potential trajectory paths and identify potential shoreline impact in the event of the worst-case discharge (WCD) from a point associated with the proposed Texas Gulflink Project. The proposed Project consists of approximately 45 miles of 42-inch-diameter pipeline extending from a proposed on-land pump to a proposed deepwater port (DWP). The proposed DWP consist of two single point mooring (SPM) buoy systems which serve as the primary floating component used for the loading of moored vessels with crude oils for export. The proposed DWP is located within the Gulf of Mexico, approximately 30 miles from the shoreline of Brazoria County, Texas. Trajectory paths were simulated from 5 locations along the pipeline route extending from the proposed on-land station to a midpoint between the platform and shore. The modeling results are derived from monthly and average condition trajectory model runs for each site using an average from different crudes that would be transferred to the DWP. Each model run was analyzed to determine any potential environmental and/or socioeconomic impacts. It is important to differentiate that the models are deterministic and not stochastic. The models depict a potential outcome with the implementation of averaged currents and weather conditions for the area of interest.

SITES AND SURROUNDING AREA DESCRIPTION

The proposed platform is located at 28° 33' 18.00" N, 95° 01' 42.00" W, approximately 30 miles offshore of Matagorda Island, Texas. The first WCD release location is Midpoint along the pipeline 28° 41' 5.9" N, 95° 14' 48.59" W, located approximately 15 miles offshore in depths near 70 feet. The second WCD release location is one mile offshore along the proposed pipeline at 28° 51' 11.634" N, 95° 23' 14.834" W in depths near 30 feet. The third WCD release location is where the proposed pipeline crosses the Intracoastal Waterway at 28° 53' 55.4" N, 95° 23' 41.7" W with depths near 30 feet. The fourth WCD release location is where the proposed pipeline crosses the Brazos River at 28° 55' 22.269" N, 95° 23' 9.692" W with depths near 20 feet. The fifth WCD release location is where the proposed pipeline crosses Jones Creek at 28° 57' 9.722" N, 95° 25' 34.254" W with depths near 5 feet.

Areas surrounding the proposed sites include Galveston, Brazoria, Matagorda, and Calhoun Counties. State and federal lands include: Matagorda Island, Mad Island WMA, San Bernard WMA, Peach Point WMA-Bryan Beach, Brazoria National Wildlife Refuge, and Galveston Island State Park.

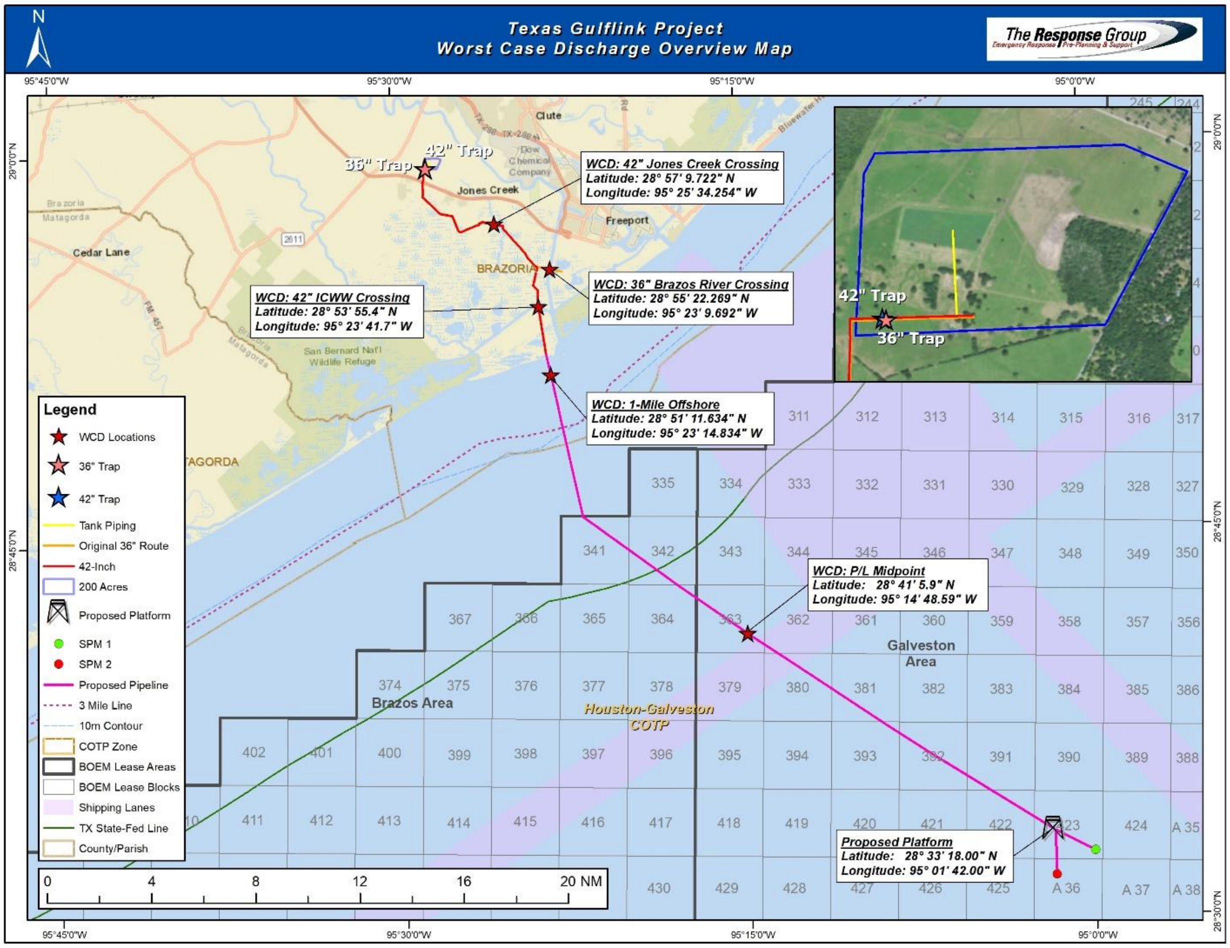


Figure 1 – Overview of area surrounding Proposed Site and defined Worst Case Discharge locations

MODEL PARAMETERS: OFFSHORE

MODEL BACKGROUND

The trajectory models in this study were created using RPS ASA's OILMAP trajectory modeling software. The software allows us to create multiple deterministic models, based on defined winds and currents. The results provide the potential outcome of a release from the WCD locations of a single crude (API 50.2) during monthly averaged periods. For these models, average winds, currents, tides, and water temperatures were used. The results of the Trajectory Models presented herein assumes no response efforts were employed and therefore no oil was contained, recovered, or diverted. However, in the actual situation of an unanticipated discharge, highly-trained tactical response teams would be mobilized immediately to initiate mitigation efforts. The WCD volume used in the trajectory models is based on the entire contents of the offshore pipelines, irrespective of system design measures to reduce volumes released as a result of a failure on the system including shutoff valves, seabed bathymetry, and pipeline depth and routing. The proposed pipeline infrastructure would be designed to close shut-off valves and shutdown pumps within 30 seconds of detection of pipeline pressure drops. A full HAZOP of the system will be completed during detail design to ensure that the consequences of different credible scenarios and actions is mitigated to the lowest practical spill volume.

RELEASE PARAMETERS

The release volume is based on the potential gravity driven pipeline displacement leakage at specific locations along the pipeline, support documentation provided below in "Conditions for a Worst Case Release".

WINDS

The winds used in the models were derived from both pilot charts and NOAA National Centers for Environmental Information. Wind velocities and directions are averaged over a five year period from 2010 to 2014. The data from NOAA was sourced from blended satellite observations at a global resolution of one-quarter degrees.

CURRENTS

Currents used in the models are historic currents collected from 2010 to 2014 and were averaged over the five year period and were subset by month.

Average current data was accessed from the Hybrid Coordinate Ocean Model (HYCOM) Global Ocean models at one-quarter degree resolution.

CONDITIONS FOR WORST CASE DISCHARGE RELEASE

Offshore Worst Case Discharge Scenarios (referencing table and discussion below):

1) Midpoint between shore and platform – 66,011 barrels released over 10 days

2) One mile offshore - 68,644 barrels released over 10 days

Pipeline Leak Location (Full Open – Sheared Pipeline)	Pump Continuous Discharge during breach (5 Min Avg) (bbls)	Pump Wind Down and Pipeline Depressurizing Leakage (bbls)	Gravity Driven Pipeline Displacement Leakage						Total Leaked after 10 days (bbls)
			Length of pipe below breach (mi)	Total Volume that could leak out (bbls)	Volume Leaked After 1 Day	Volume Leaked After 2 Day	Volume Leaked After 6 Day	Volume Leaked After 10 Day	
Just Offshore	2,042 MBPD (0.126 min) 3,300 MBPD (0.321 min) 3,251 MBPD (4.553 min) **Total = 11,193 bbls**	1,844	35	290,833	10,909	19,822	41,858	55,607	68,644
Midpoint between Shore and Platform	2042 MBPD (0.502 min) 2616 MBPD (4.498 min) **Total = 8,883 bbls**	1,521	17.5	145,417	10,909	19,822	41,858	55,607	66,011

When calculating worst case discharges for the pipelines offshore, and as defined by EP Consult in *Exchange Flow of Oil and Seawater in Leaking Subsea Pipelines:* There are several mechanisms that will drive oil out of a leaking subsea crude oil pipeline. For pipelines that operate at a pressure above the hydrostatic pressure of the sea, the discharge is driven initially by the excess of the internal pressure over the external pressure. On detecting the leak, the operator will shut down the pipeline by stopping pumps and closing isolation valves. Residual pressure will then drive out a further quantity of oil (the pipeline contracts and the oil expands as the residual pressure dissipates). The pipeline then arrives at a condition where the internal pressure at the leak orifice equilibrates with the hydrostatic pressure of the sea.

At this stage, the pipeline is still oil-filled. It is often erroneously assumed that the oil stops leaking out at this time. The reality is that leakage continues due to the density difference between seawater and oil. The heavier seawater intrudes into the pipeline via the lower part of the leak orifice, and the lighter oil is displaced from the pipeline via the upper part of the leak orifice. Since the discharge of oil from an isolated pipeline is from a closed volume, the outflow of oil is matched by an equal inflow of water.

The intruding water flows along the bottom of the pipeline as a gravity current, until the moving water front encounters either the end of the pipeline or a natural trap – a location where there is sufficient local increase in pipeline elevation to prevent the water front traveling further. At the end of the pipeline, or at a trap, the water front is reflected. The oil leakage then continues until the entire pipeline segment is full of water, and all the oil has been displaced from the segment, apart from any small quantity that may be left behind clinging to the pipe walls.

OFFSHORE TRAJECTORY MODEL SUMMARY

SUMMARY – MIDPOINT OF PIPELINE

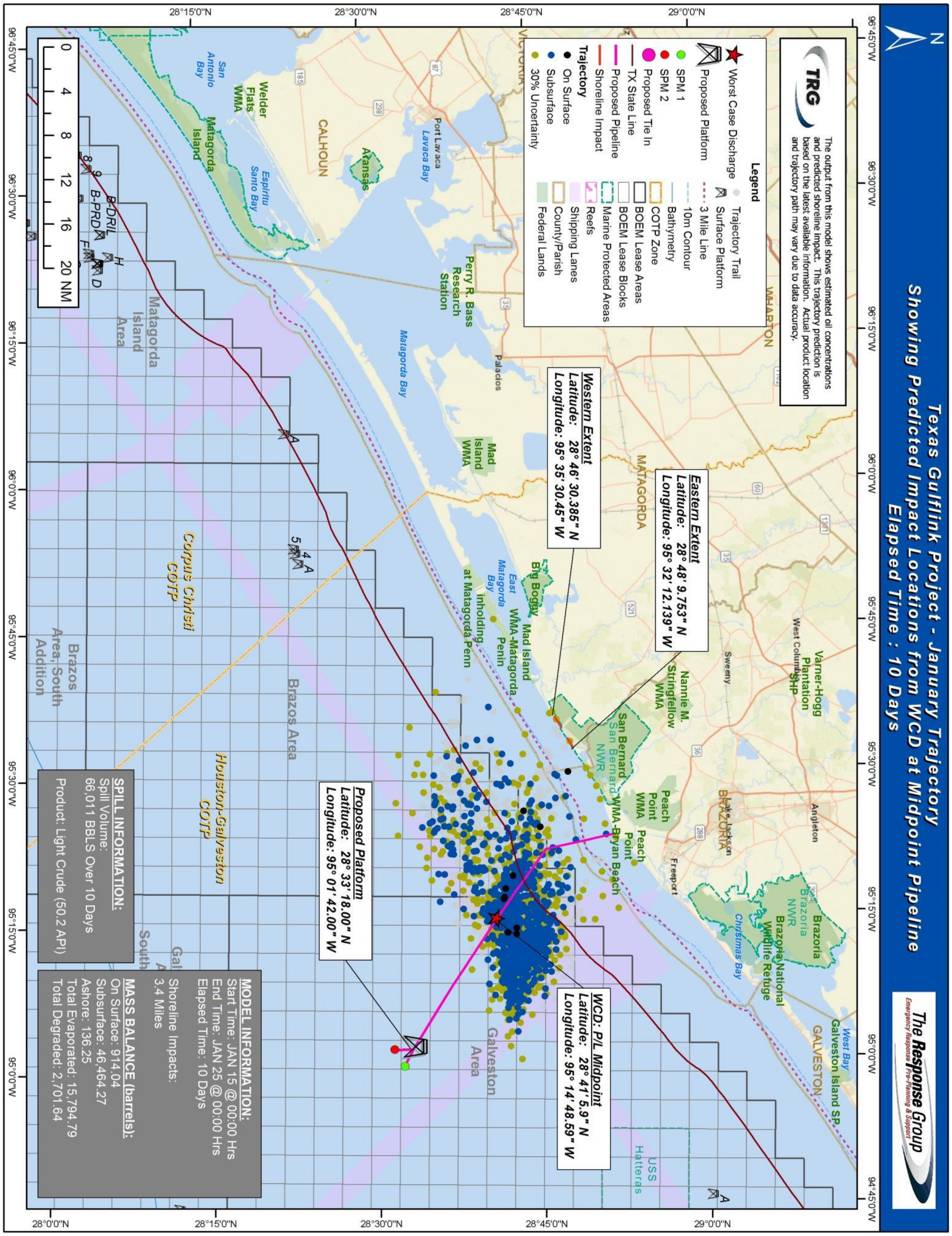
Months	*On Surface*	*Subsurface*	*Ashore*	*Evaporated*	*Degraded*
January	**914.04**	**46,464.27**	**136.25**	**15,794.79**	**2,701.64**
February	**601.31**	**46,383.74**	**405.13**	**15,953.82**	**2,666.99**
March	**695.41**	**46,201.21**	**451.65**	**16,002.60**	**2,660.13**
April	**506.41**	**46,454.98**	**176.88**	**16,274.63**	**2,598.10**
May	**695.41**	**46,201.37**	**451.49**	**16,002.44**	**2,660.29**
June	**554.87**	**46,320.91**	**92.88**	**16,520.16**	**2,522.18**
July	**555.68**	**46,358.87**		**16,573.47**	**2,522.98**
August	**909.44**	**42,375.42**	**3,947.10**	**16,275.44**	**2,503.60**
September	**556.49**	**46,389.56**		**16,534.70**	**2,530.25**
October	**659.06**	**46,512.33**		**16,243.13**	**2,596.48**
November	**598.49**	**46,652.86**		**16,135.71**	**2,623.94**
December	**747.91**	**46,534.13**		**16,083.21**	**2,645.75**

Figure 2 – Mass Balance for Release of 66,011 Barrels Over 10 Days

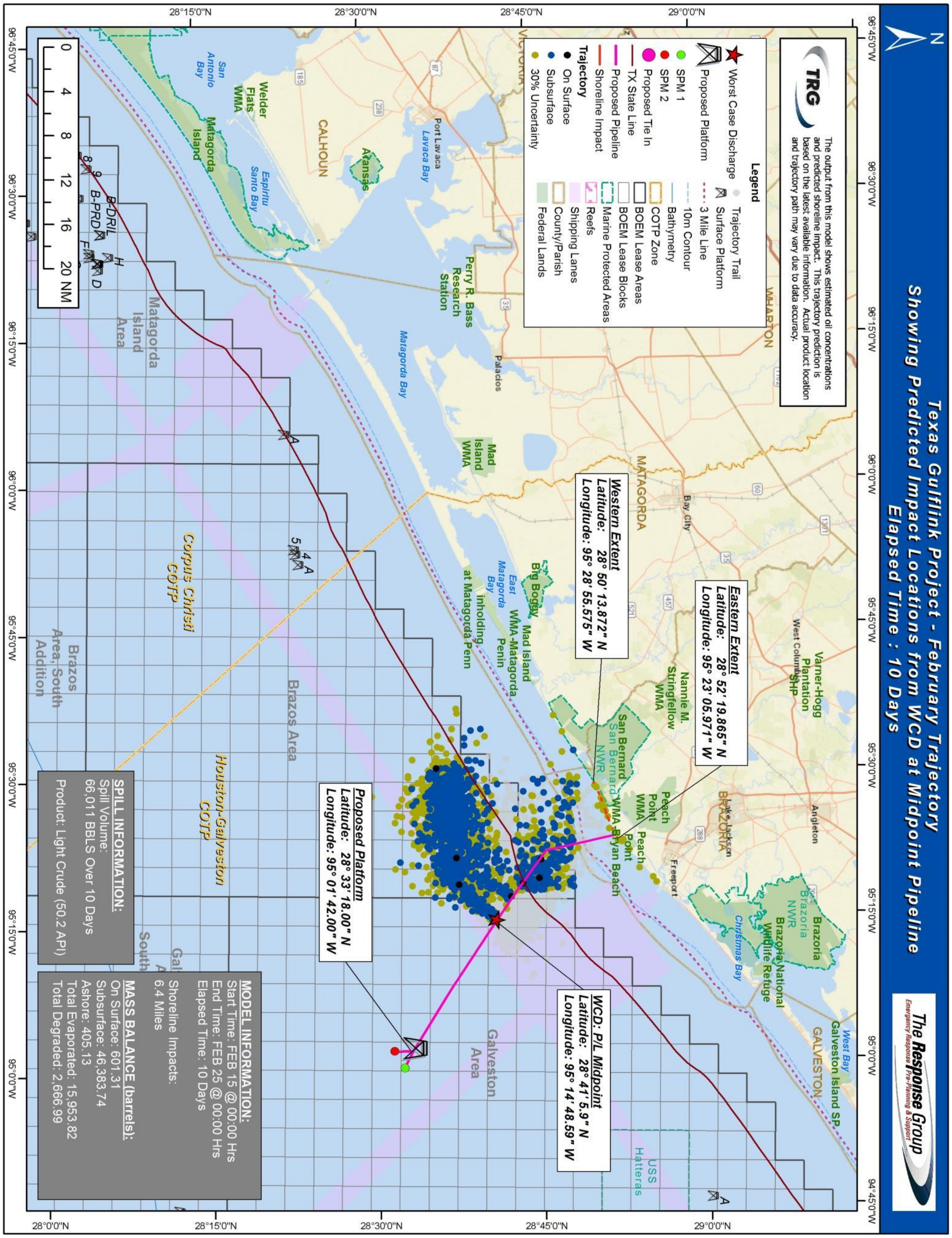
** Trajectory model assumes no response / mitigation efforts following discharge*

Initial shoreline Impacts:

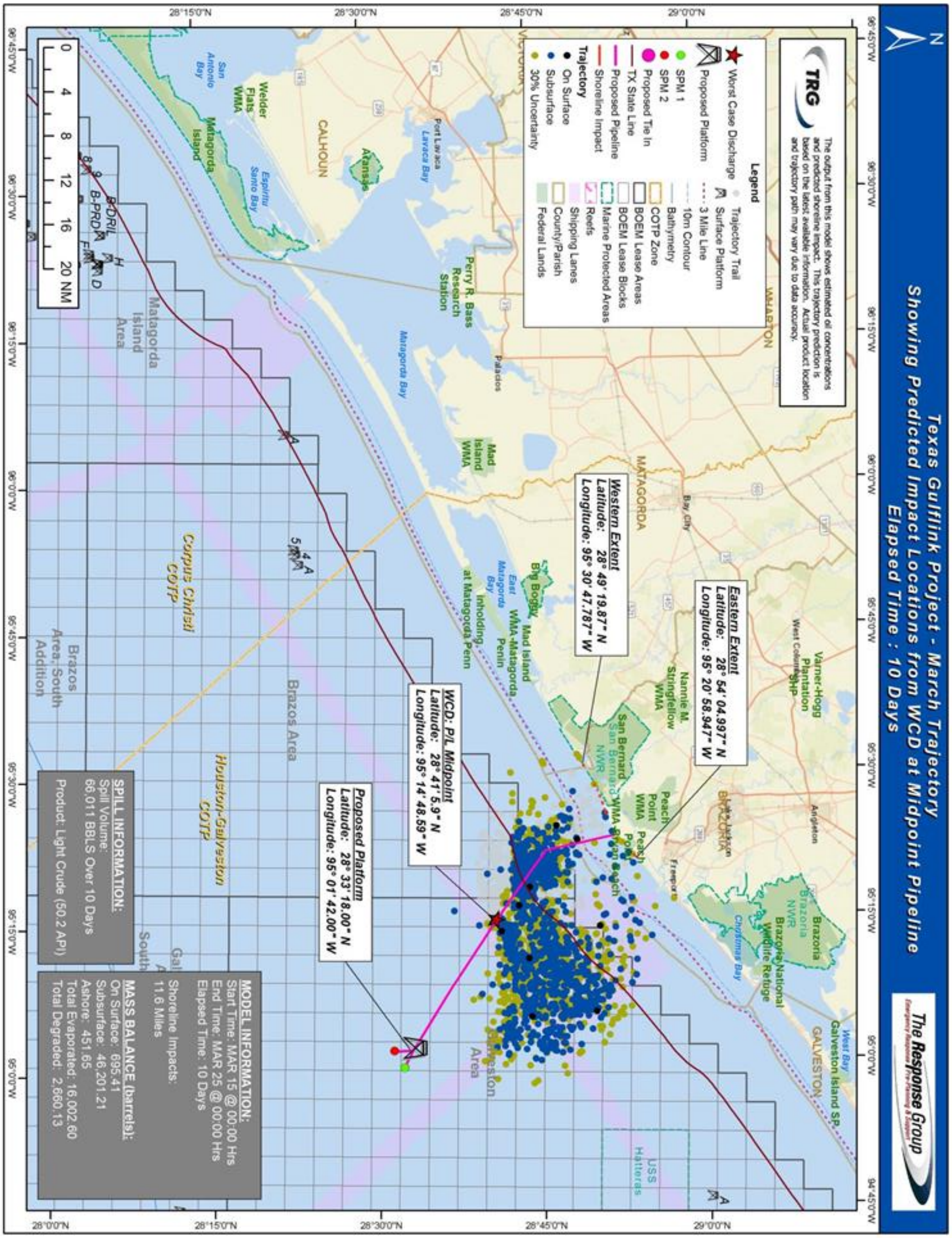
January: 4 days, 21 hours
February: 3 days, 3 hours
March: 3 days, 3 hours
April: 2 days, 5 hours
May: 3 days, 1 hour
June: 8 days, 18 hours
July: no predicted impact to shoreline within 10 days
August: 10 hours
September: no predicted impact to shoreline within 10 days
October: no predicted impact to shoreline within 10 days
November: no predicted impact to shoreline within 10 days
December: no predicted impact to shoreline within 10 days



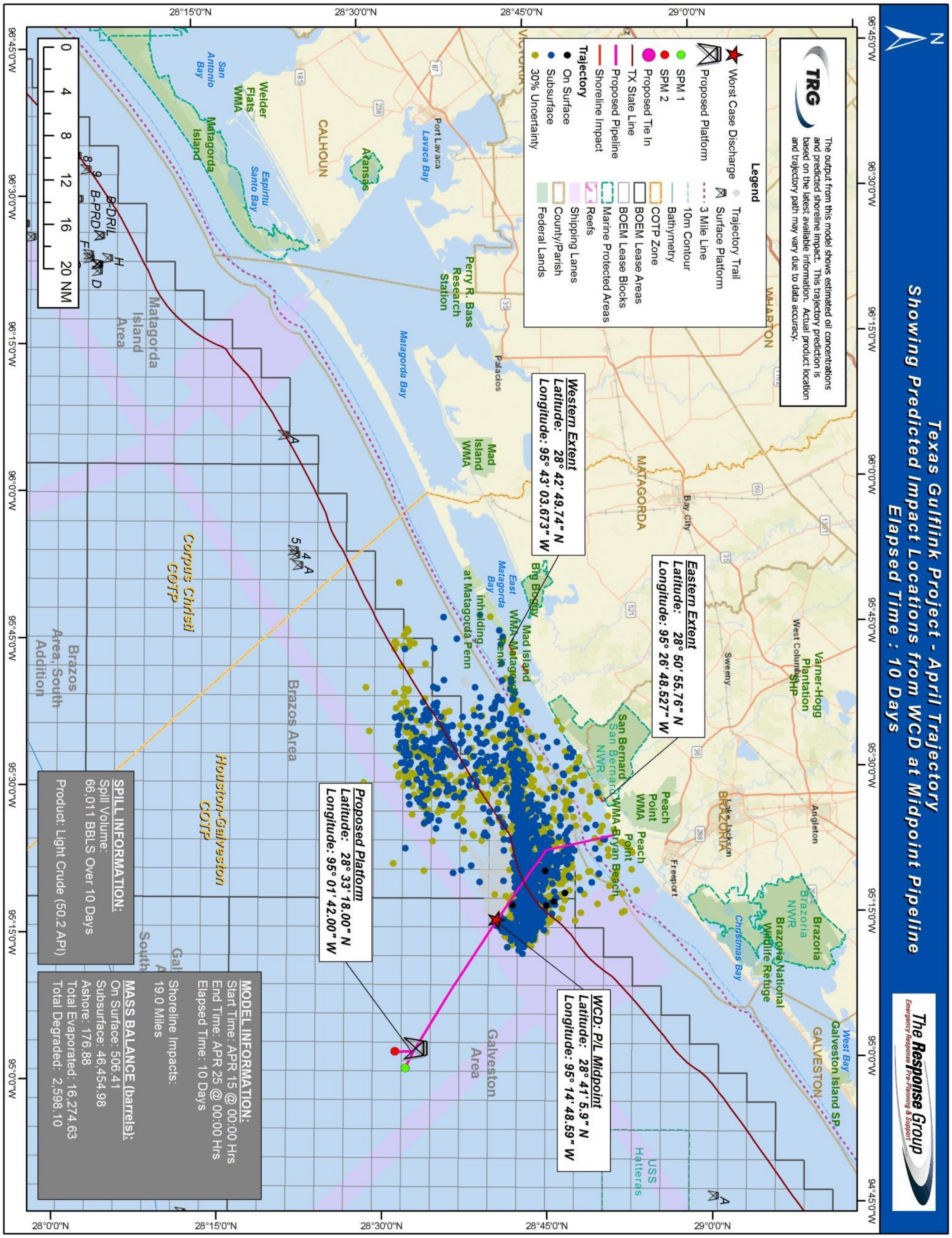
Matagorda County encompasses the predicted shoreline impact for the January model. The model estimates approximately 140 barrels are predicted to impact 3.4 miles of shoreline by day 10.



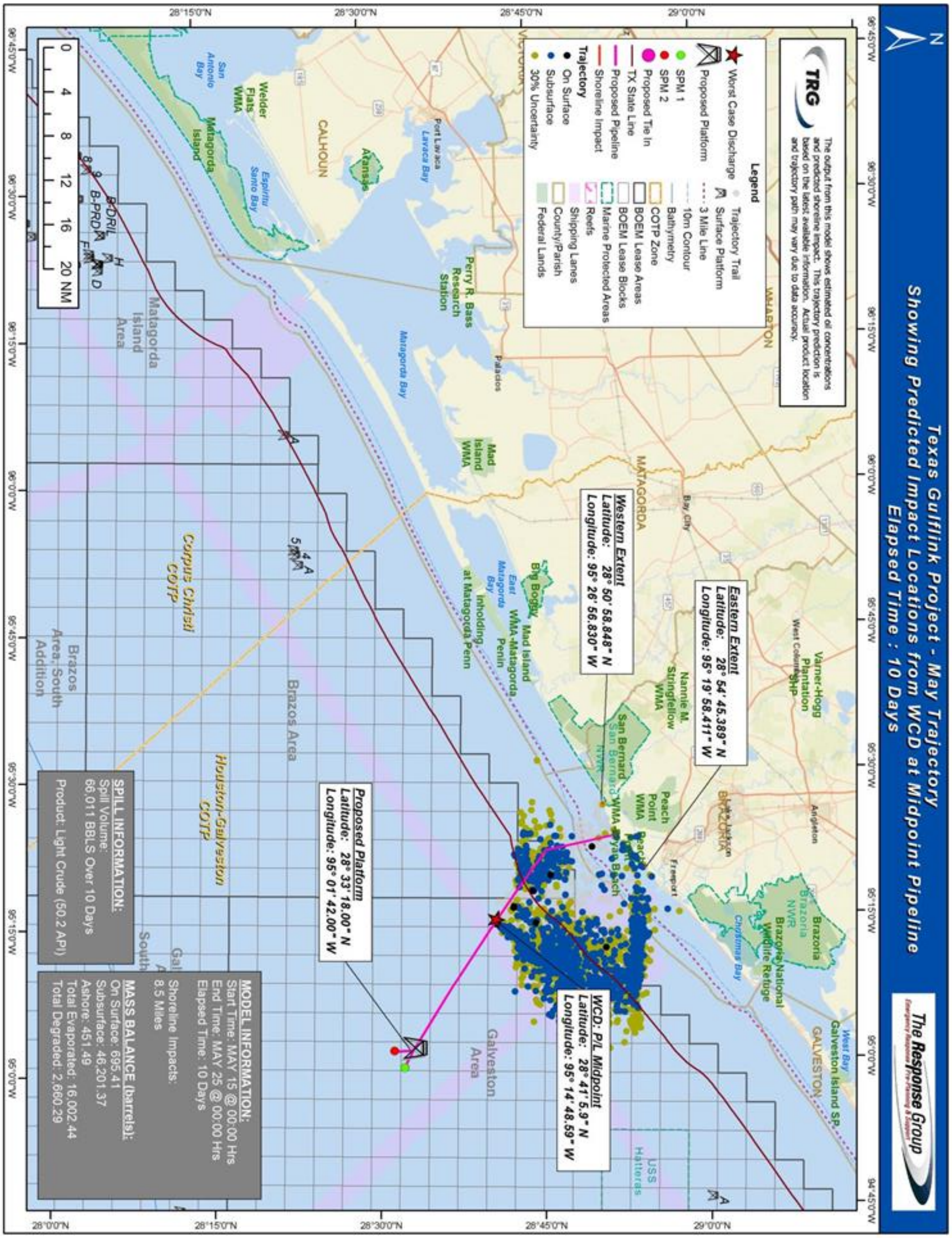
Brazoria County encompasses the predicted shoreline impact for the February model. The model estimates approximately 400 barrels are predicted to impact 6.4 miles of shoreline by day 10.



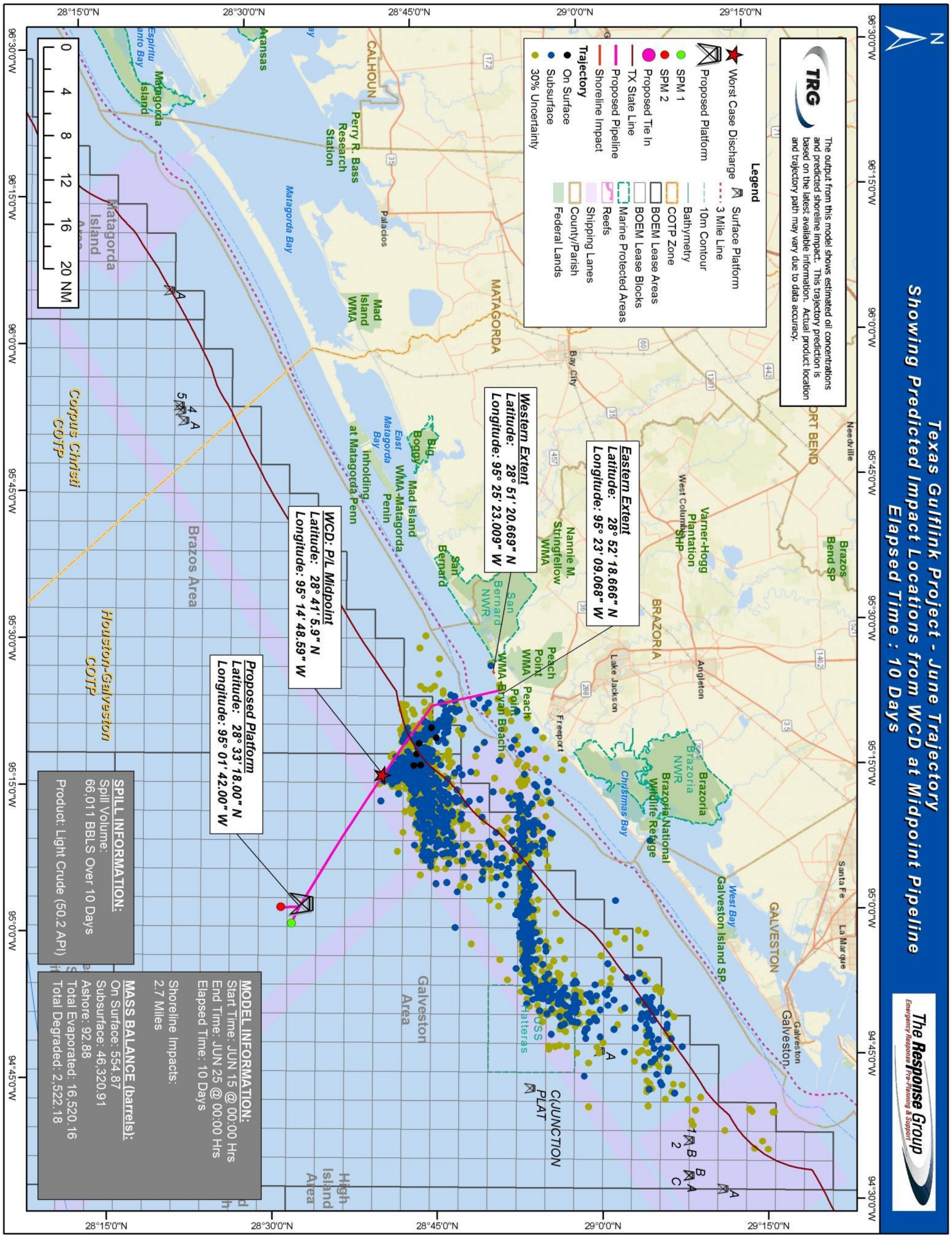
Predicted shoreline impact for the March model affects Matagorda and Brazoria counties. The model estimates approximately 450 barrels are predicted to impact 11.6 miles of shoreline by day 10.



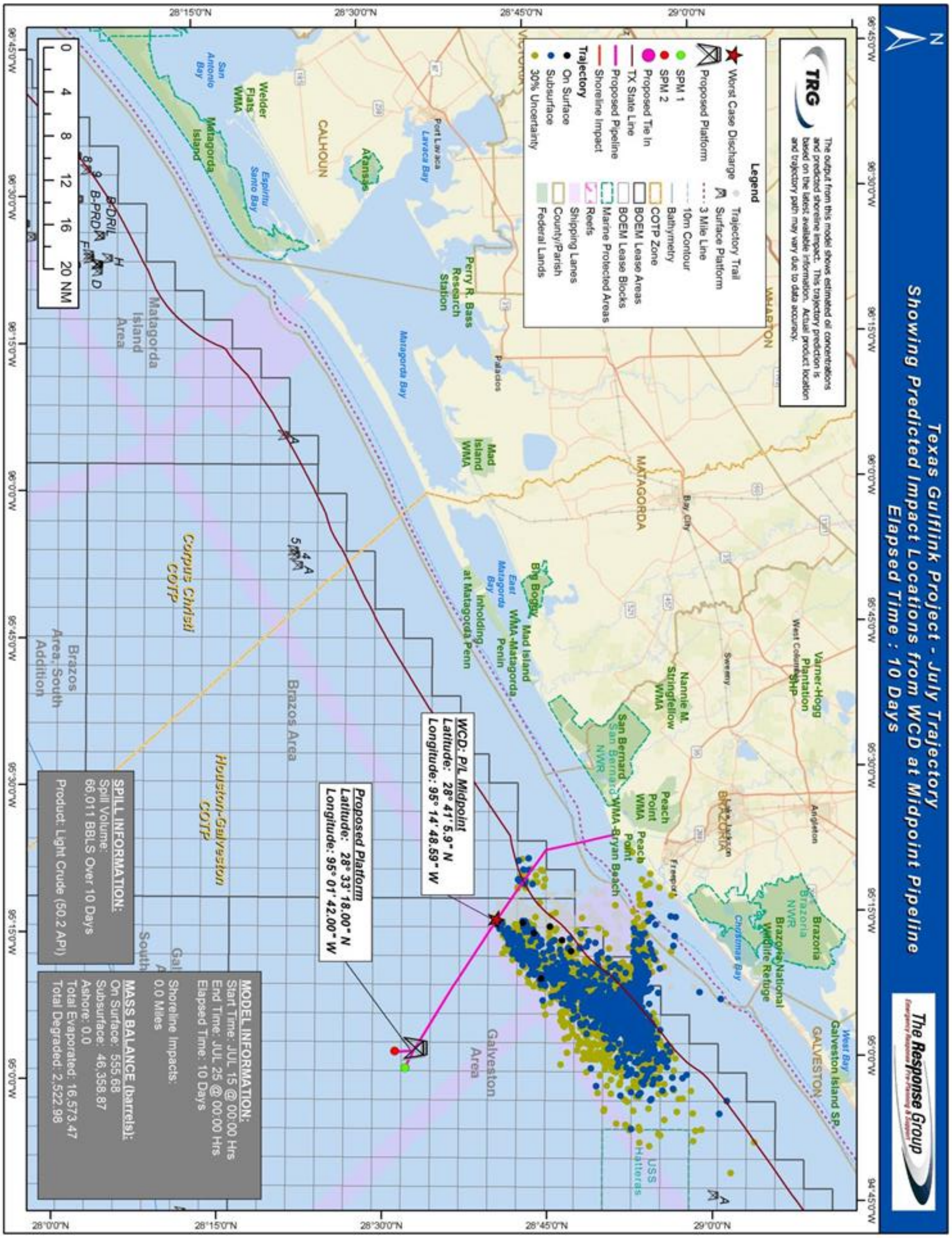
Predicted shoreline impact for the April model affects Matagorda and Brazoria counties. The model estimates approximately 180 barrels are predicted to impact 19 miles of shoreline by day 10.



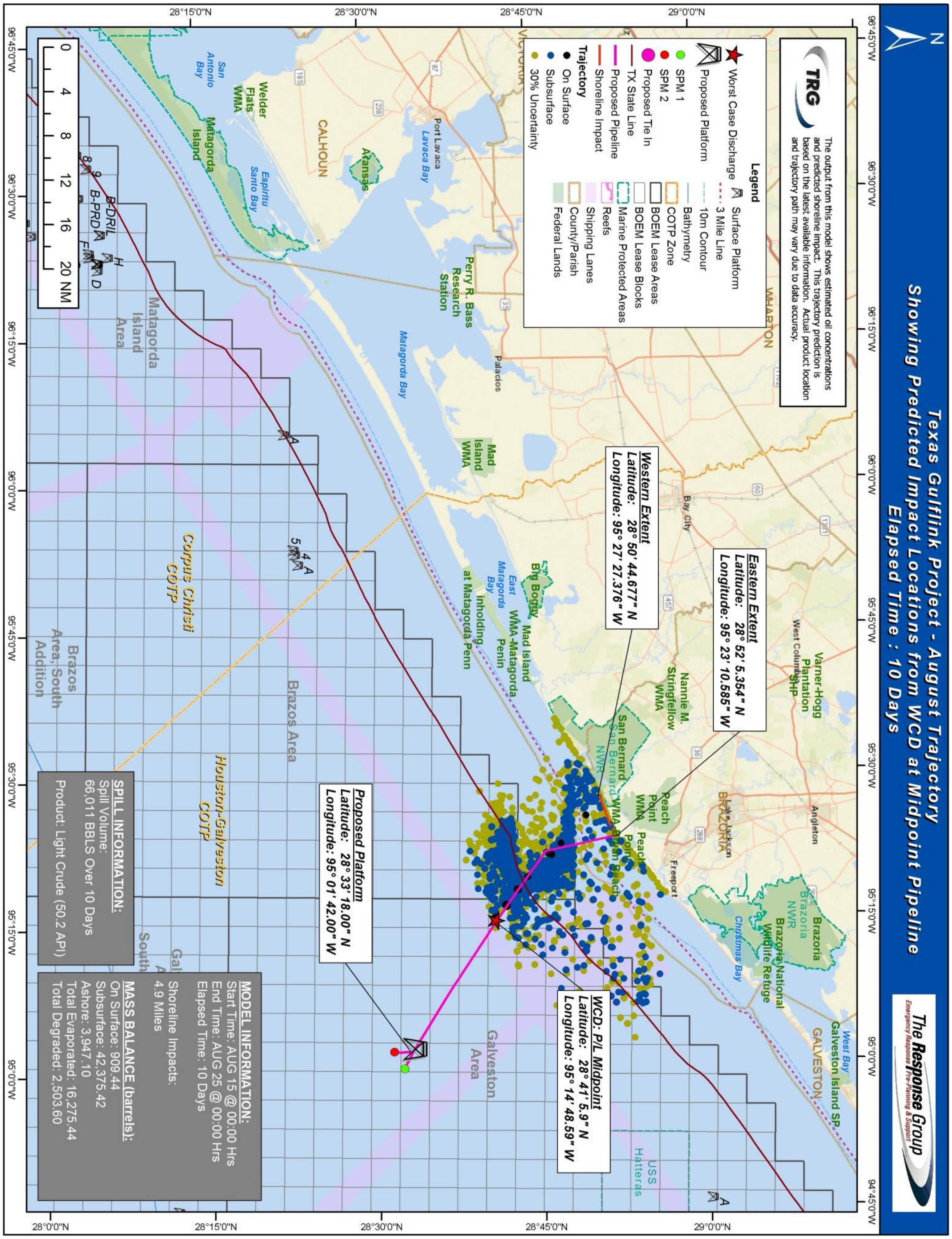
Brazoria County encompasses the predicted shoreline impact for the May model. The model estimates approximately 450 barrels are predicted to impact 8.5 miles of shoreline by day 10.



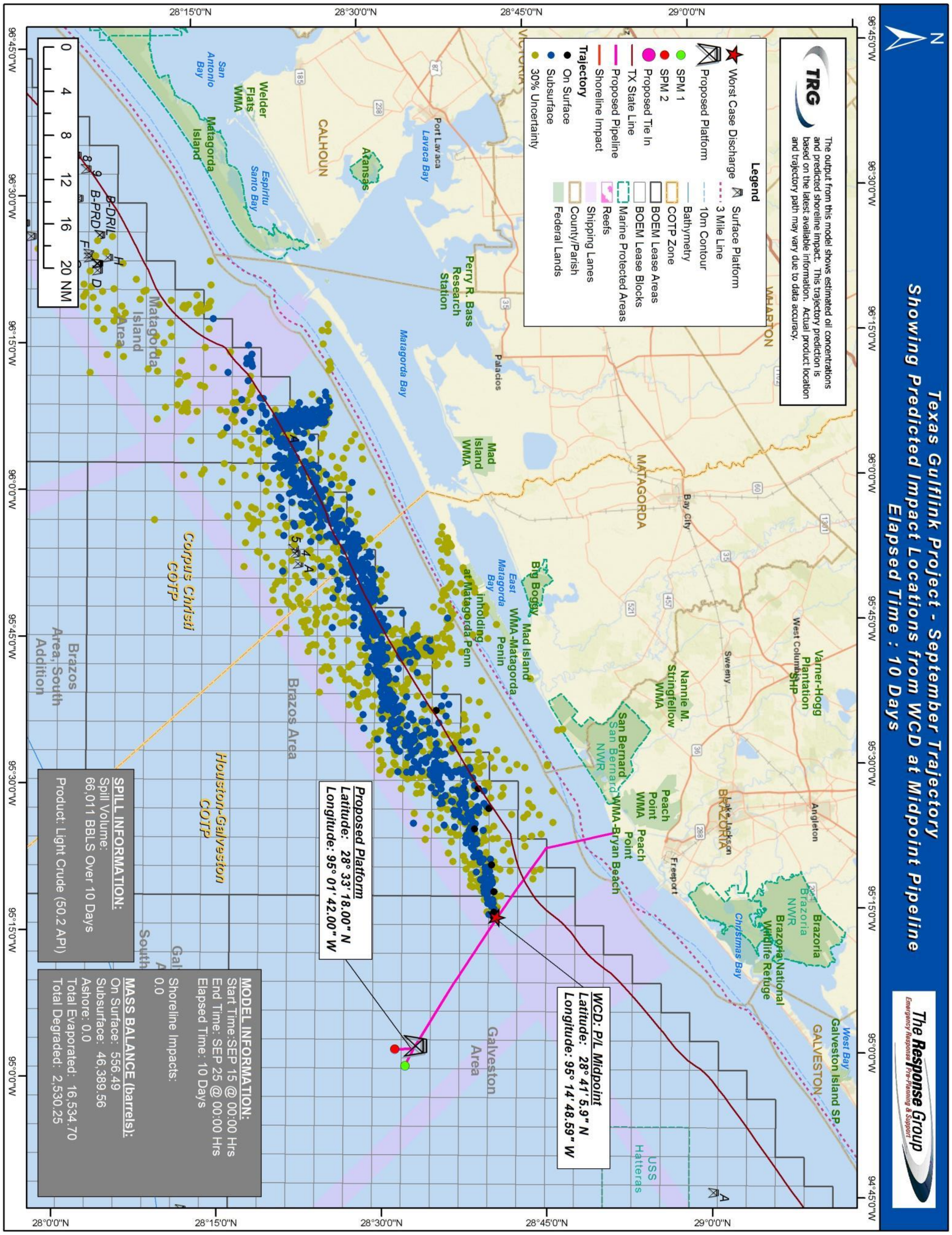
Brazoria County encompasses the predicted shoreline impact for the June model. The model estimates approximately 90 barrels are predicted to impact 2.7 miles of shoreline by day 10.



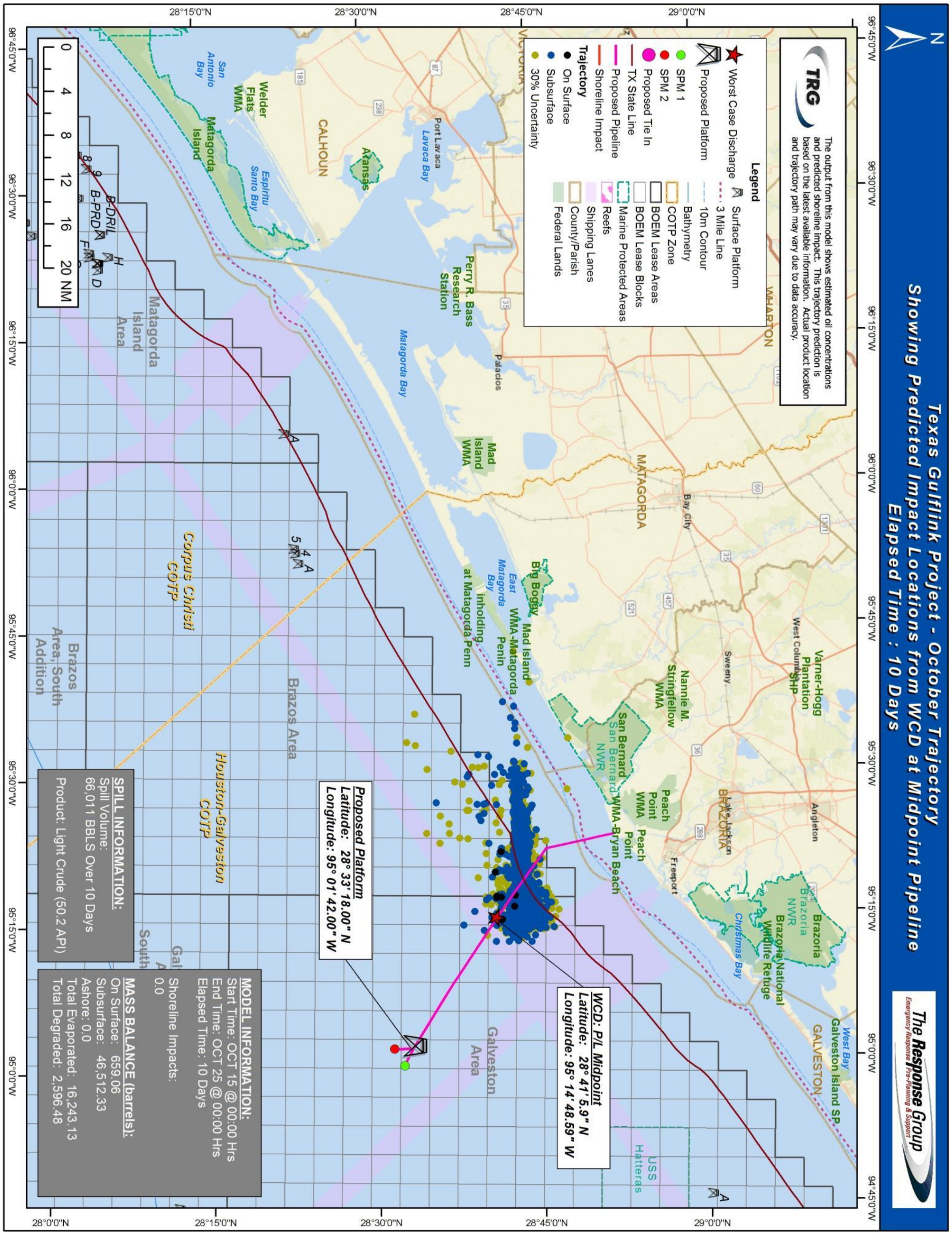
The July model estimates no shoreline impact to occur within the region from the trajectory of the surface slick.



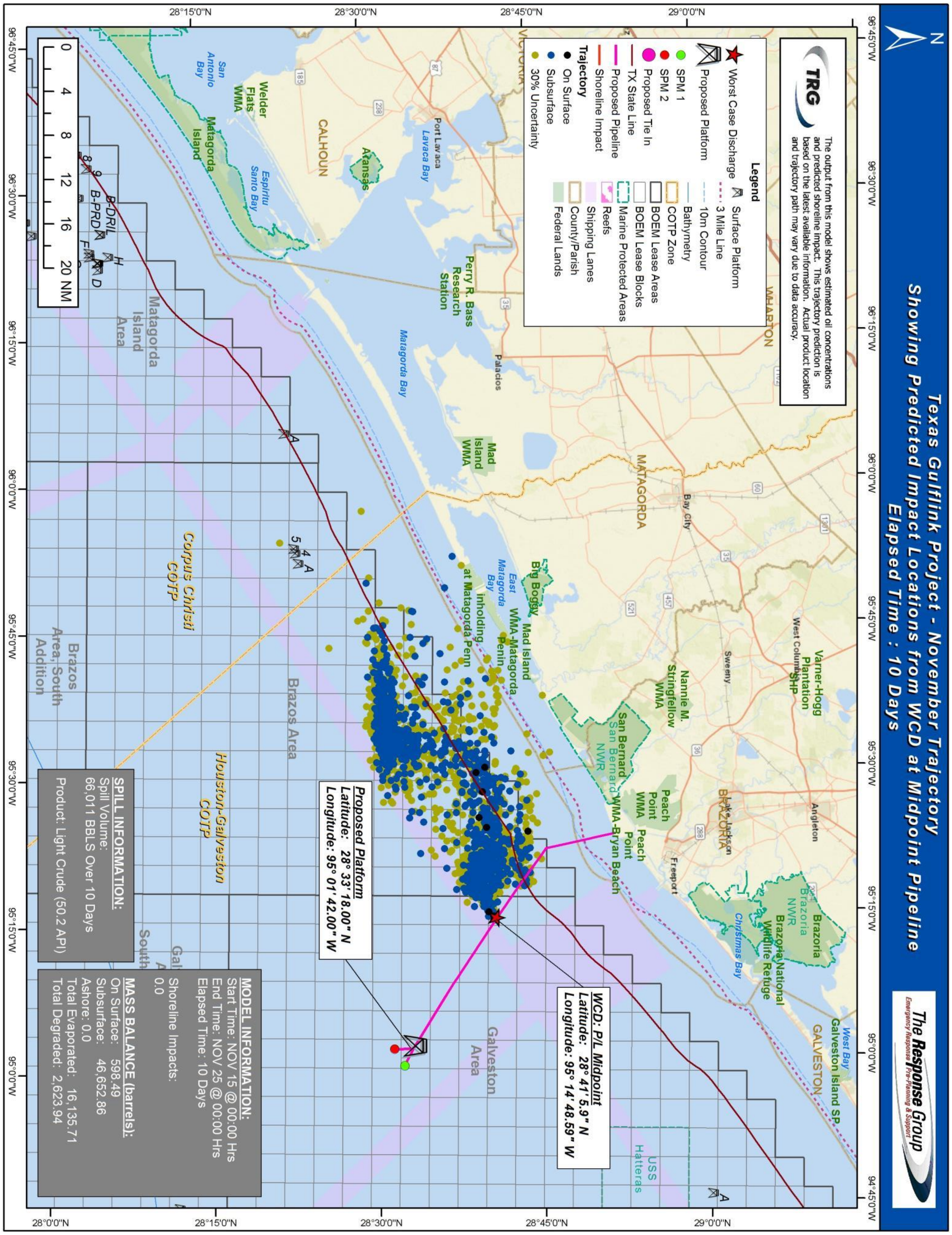
Brazoria County encompasses the predicted shoreline impact for the August model. The model estimates approximately 3,950 barrels are predicted to impact 4.9 miles of shoreline by day 10.



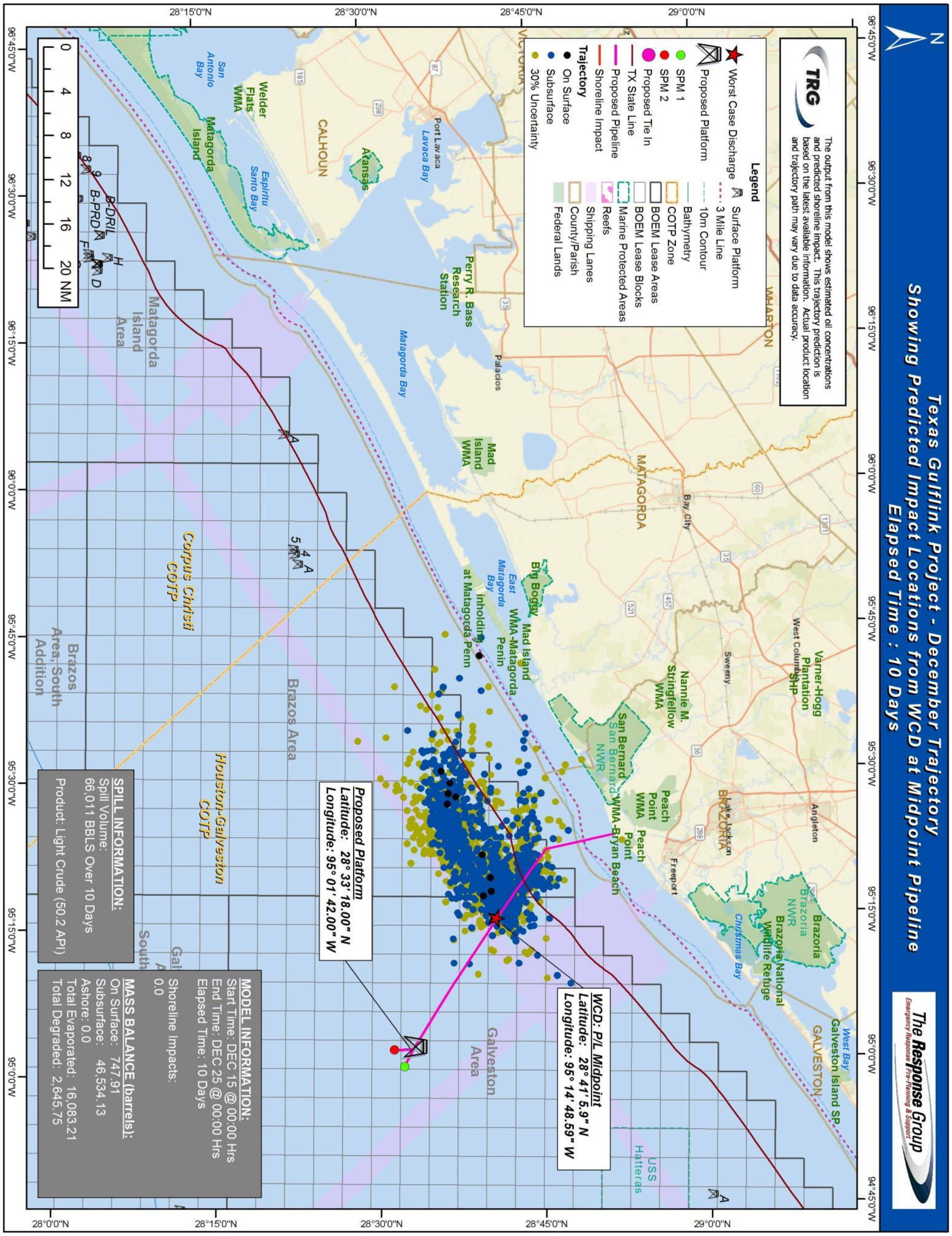
The September model estimates no shoreline impact to occur within the region from the trajectory of the surface slick.



The October model estimates no shoreline impact to occur within the region from the trajectory of the surface slick.



The November model estimates no shoreline impact to occur within the region from the trajectory of the surface slick.



The December model estimates no shoreline impact to occur within the region from the trajectory of the surface slick.

The cumulative models estimates approximately 27.3 miles of shoreline could receive impact across all months.

SUMMARY – ONE MILE OFFSHORE

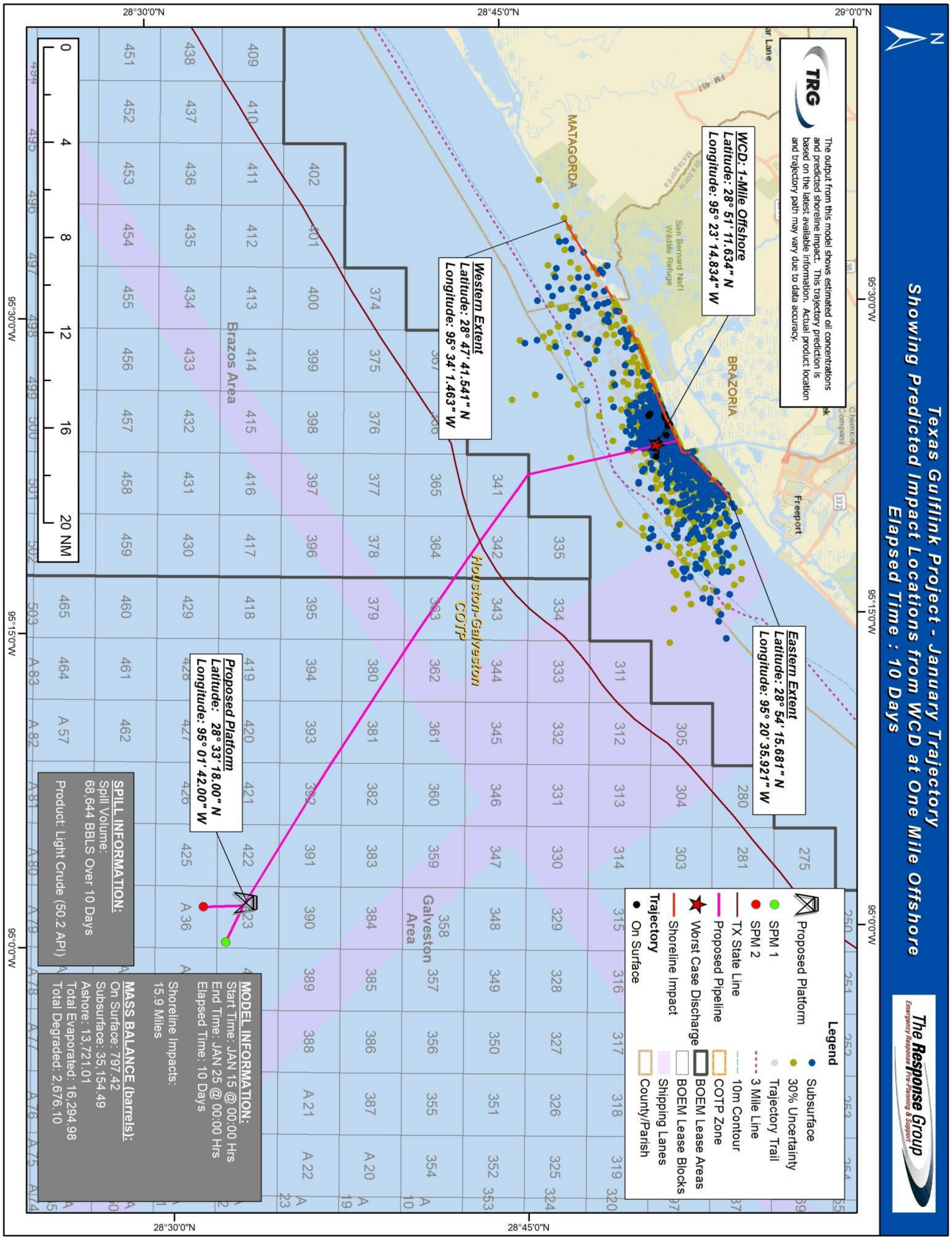
Months	On Surface	Subsurface	Ashore	Evaporated	Degraded
January	797.42	35,154.49	13,721.01	16,294.98	2,676.10
February	776.09	34,139.57	14,707.82	16,364.04	2,656.48
March	578.29	35,543.63	13,463.76	16,392.15	2,666.17
April	524.66	34,453.27	14,177.91	16,625.97	2,862.19
May	682.81	37,418.00	11,181.20	16,767.63	2,594.37
June	469.42	38,552.46	10,001.83	17,046.69	2,573.61
July	481.13	39,176.47	9,265.31	17,169.05	2,552.04
August	1048.52	39,873.25	8,319.04	16,856.56	2,546.63
September	530.88	37,372.04	11,137.02	17,043.62	2,560.44
October	530.32	38,375.90	10,388.14	16,730.97	2,618.68
November	702.76	37,258.16	11,525.83	16,510.79	2,646.46
December	735.47	34,807.60	14,056.60	16,387.78	2,656.56

Figure 3 – Mass Balance for Release of 68,644 Barrels Over 10 Days

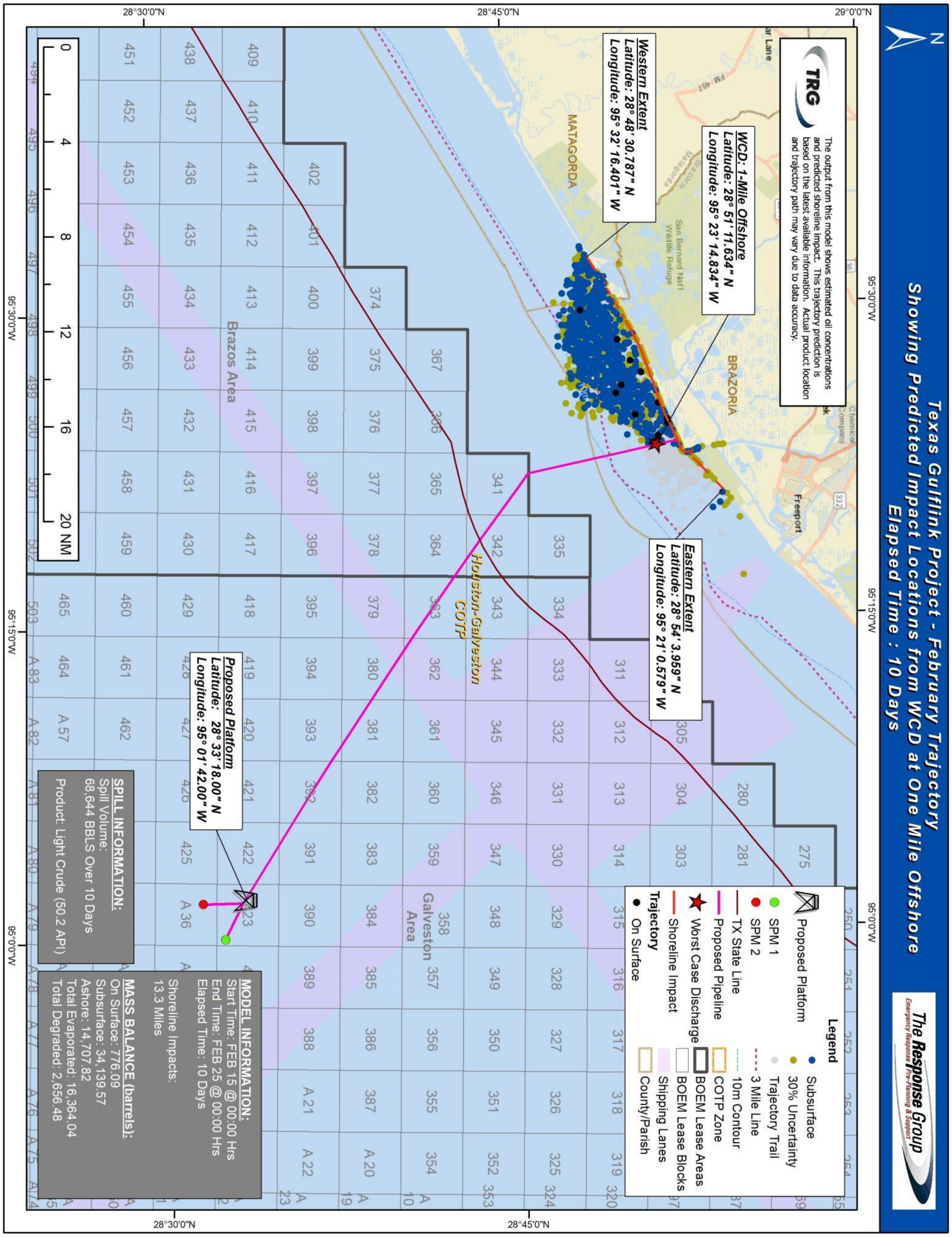
** Trajectory model assumes no response / mitigation efforts following discharge*

Initial shoreline Impacts:

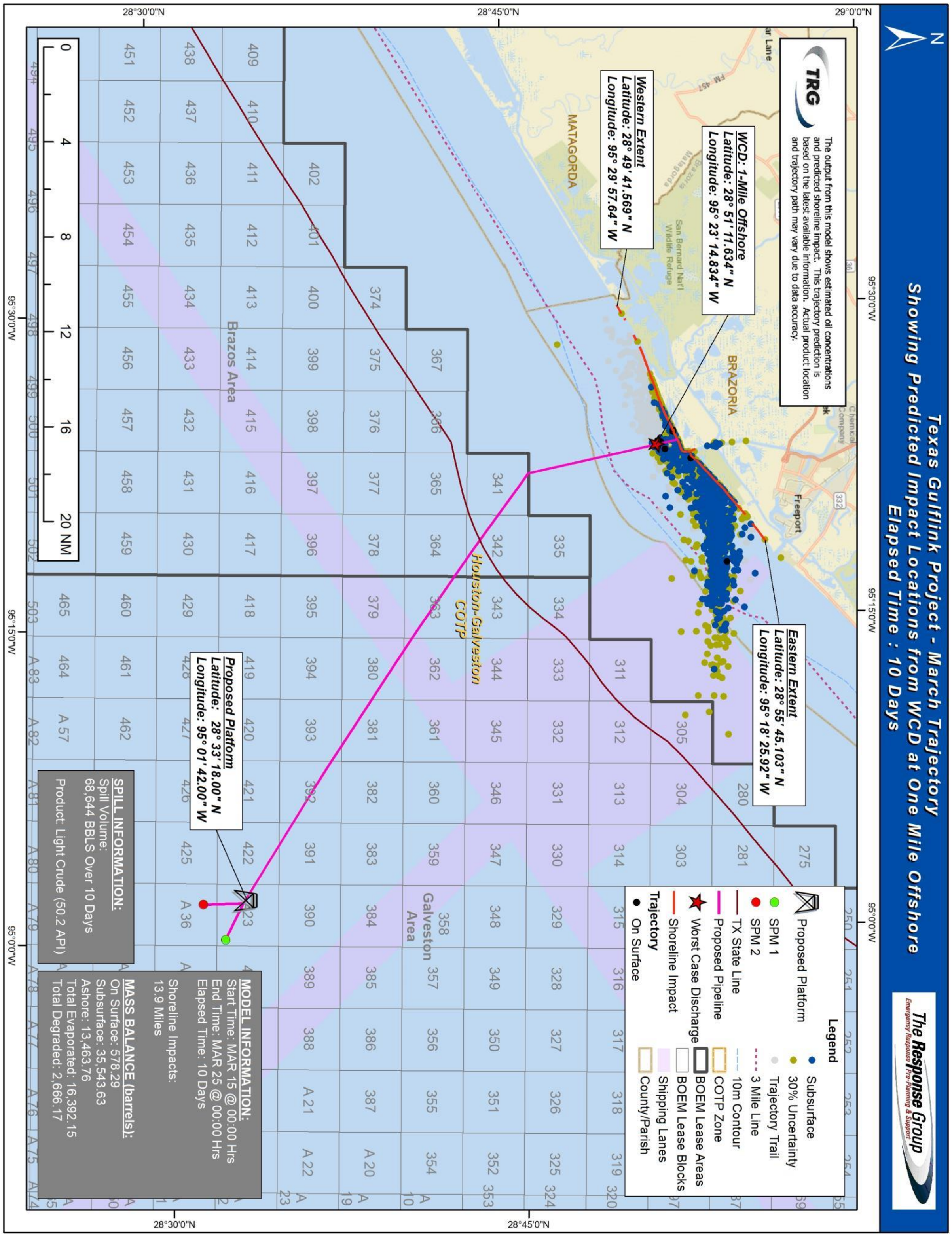
January: 2-4 Hours
February: 2-4 Hours
March: 2-4 Hours
April: 2-4 Hours
May: 2-4 Hours
June: 2-4 Hours
July: 2-4 Hours
August: 2-4 Hours
September: 2 -4Hours
October: 2-4 Hours
November: 3-4 Hours
December: 3-4 Hours



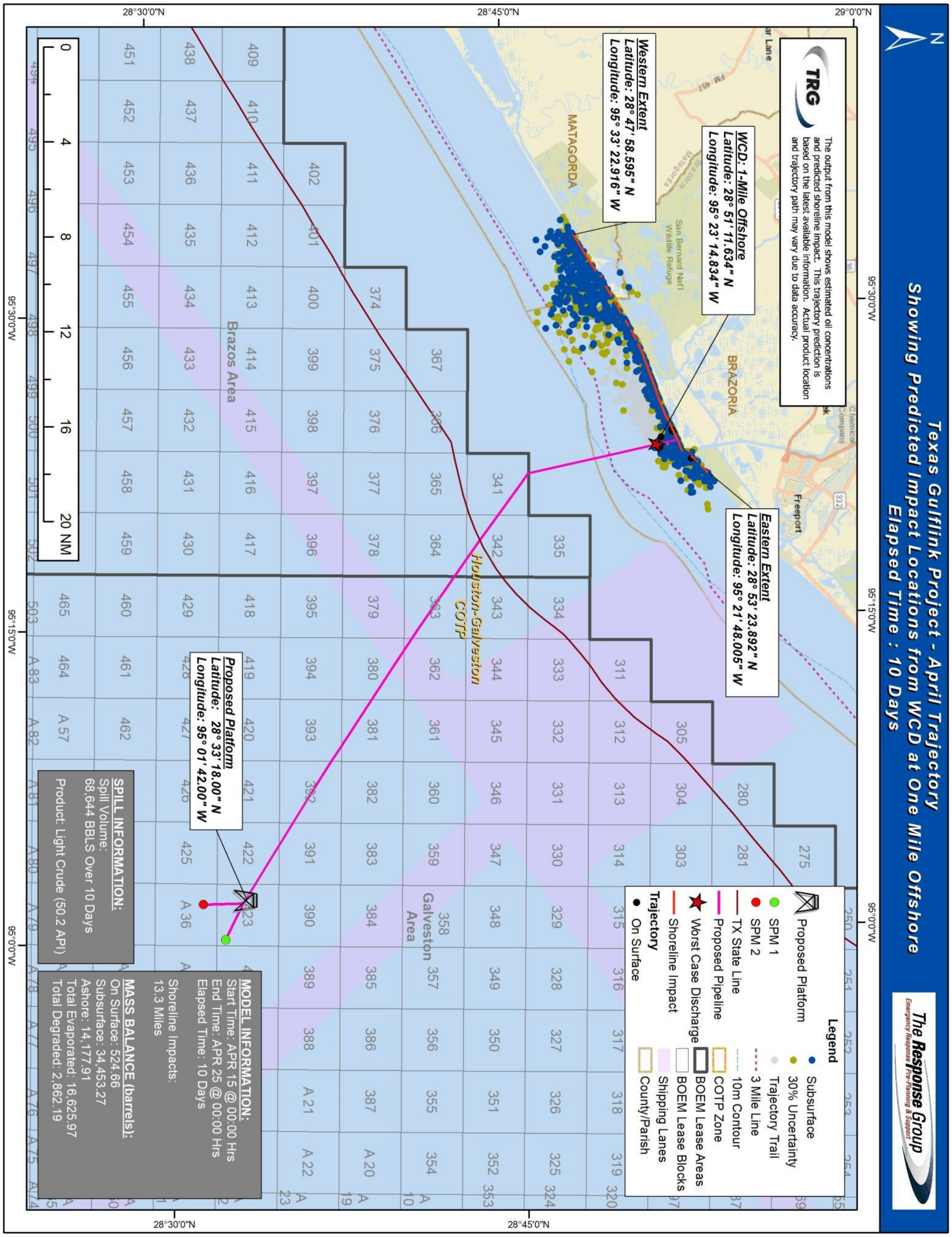
Predicted shoreline impact for the January model affects Matagorda and Brazoria counties. The model estimates approximately 13,700 barrels are predicted to impact 15.9 miles of shoreline by day 10.



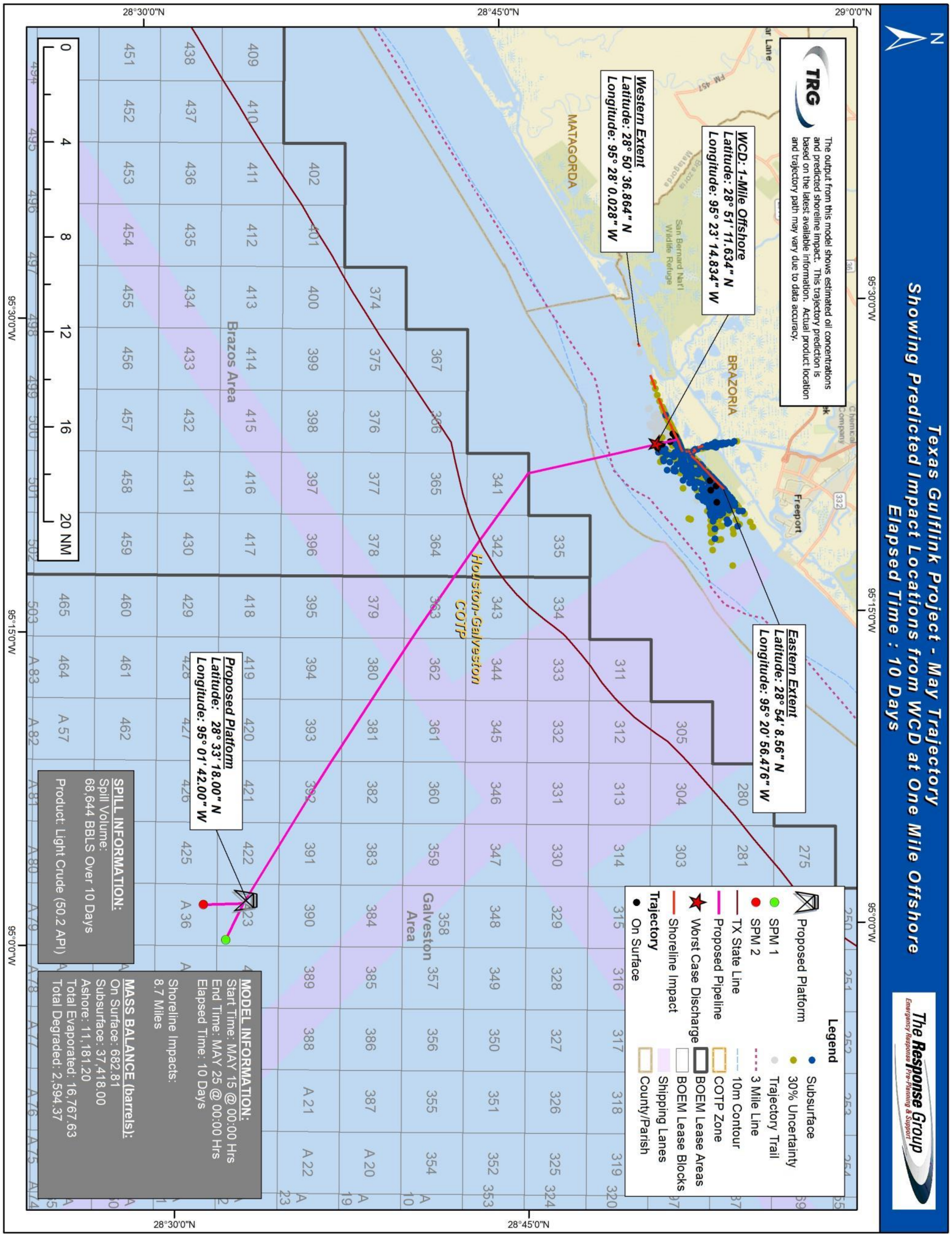
Predicted shoreline impact for the February model affects Matagorda and Brazoria counties. The model estimates approximately 14,700 barrels are predicted to impact 13.3 miles of shoreline by day 10.



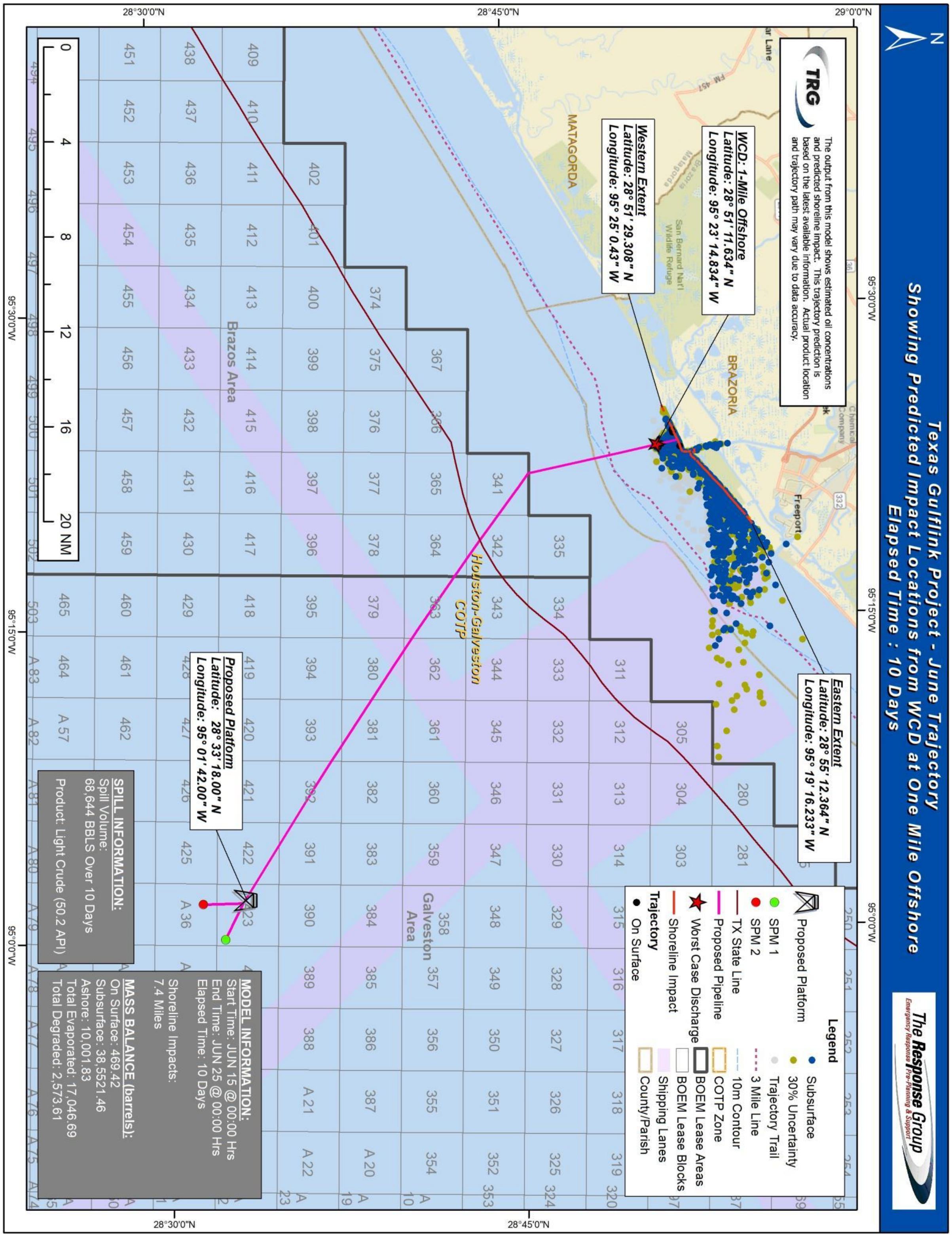
Brazoria County encompasses the predicted shoreline impact for the March model. The model estimates approximately 13,500 barrels are predicted to impact 13.9 miles of shoreline by day 10.



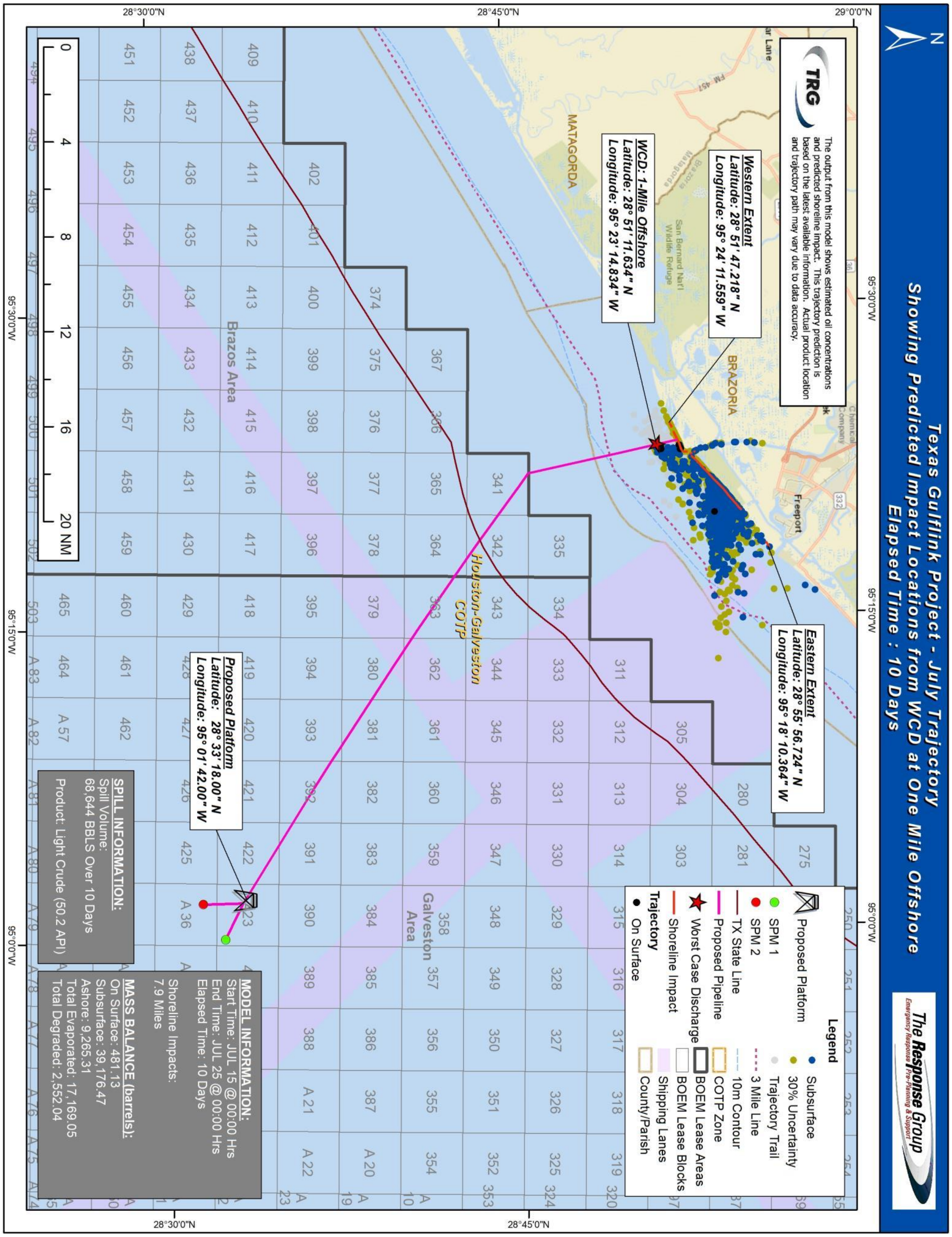
Predicted shoreline impact for the April model affects Matagorda and Brazoria counties. The model estimates approximately 14,200 barrels are predicted to impact 13.3 miles of shoreline by day 10.



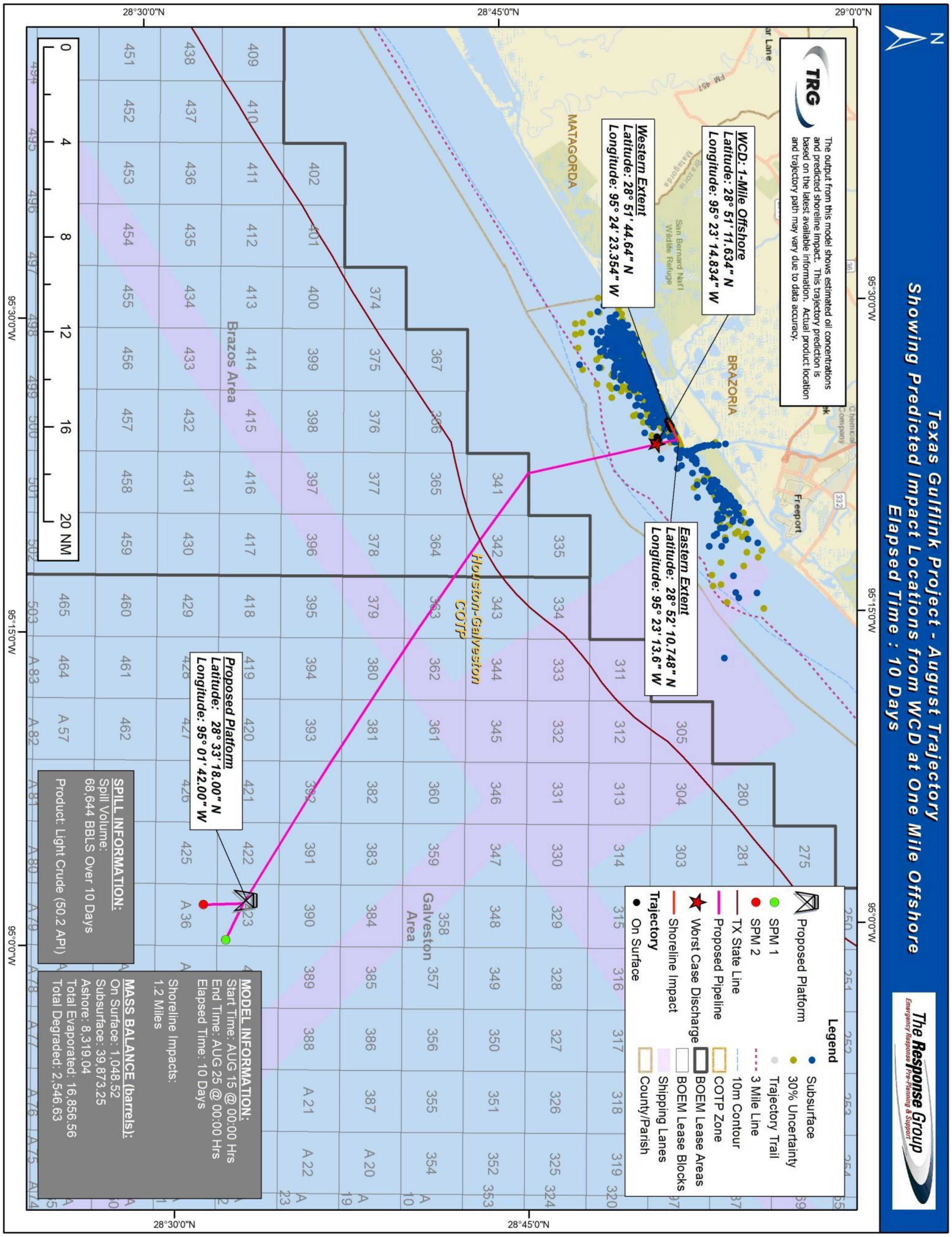
Brazoria County encompasses the predicted shoreline impact for the May model. The model estimates approximately 11,200 barrels are predicted to impact 8.7 miles of shoreline by day 10.



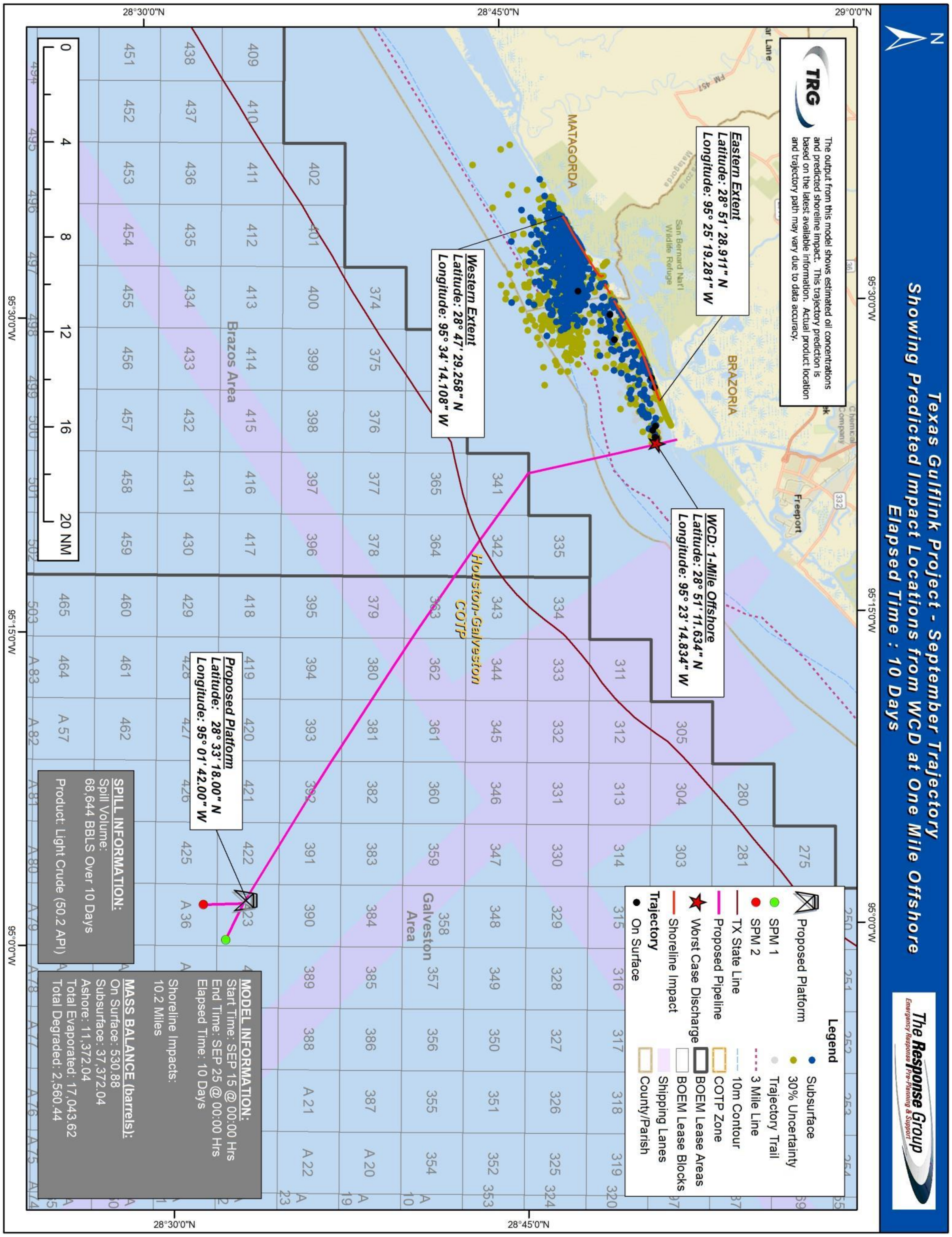
Brazoria County encompasses the predicted shoreline impact for the June model. The model estimates approximately 10,000 barrels are predicted to impact 7.4 miles of shoreline by day 10.



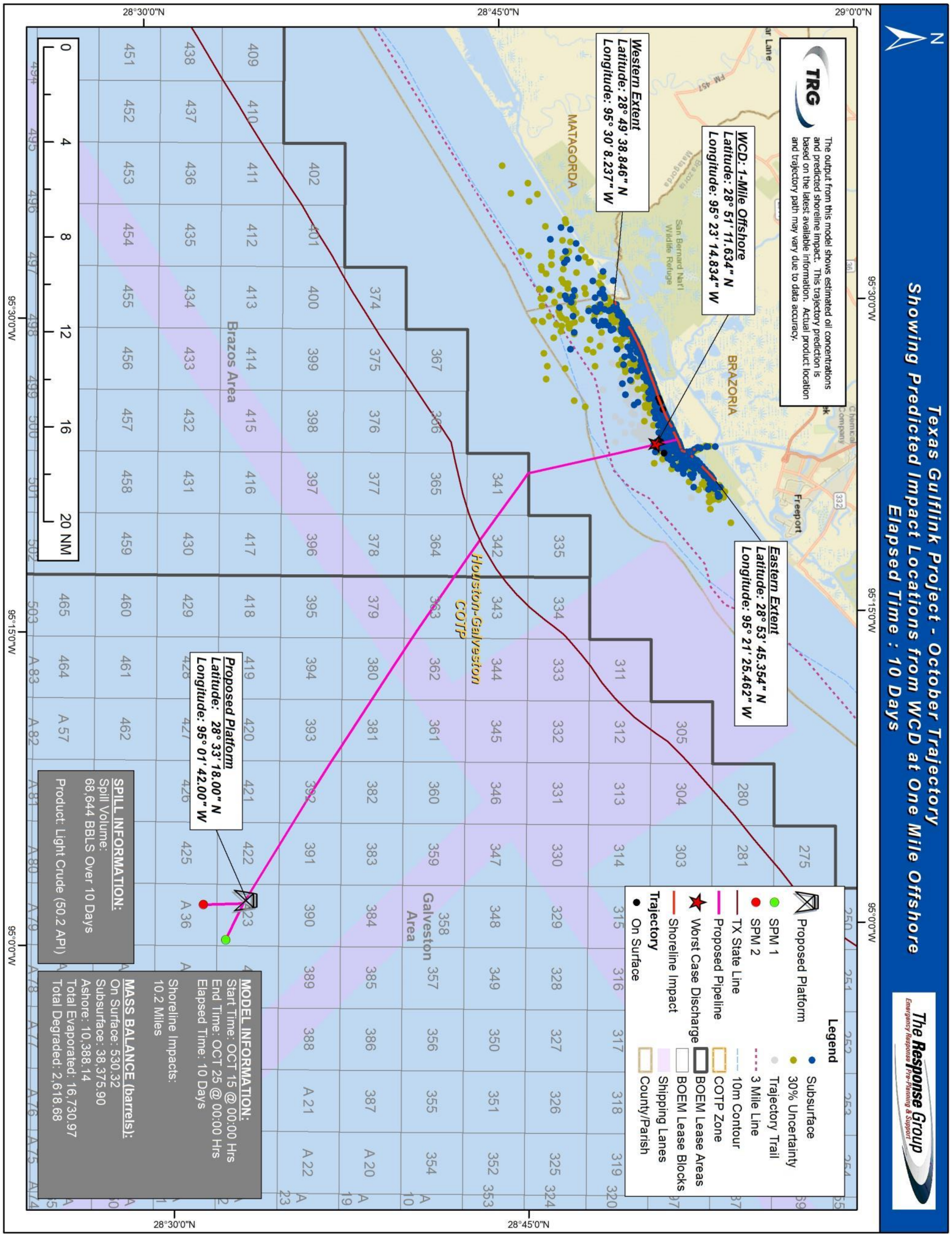
Brazoria County encompasses the predicted shoreline impact for the July model. The model estimates approximately 9,300 barrels are predicted to impact 7.9 miles of shoreline by day 10.



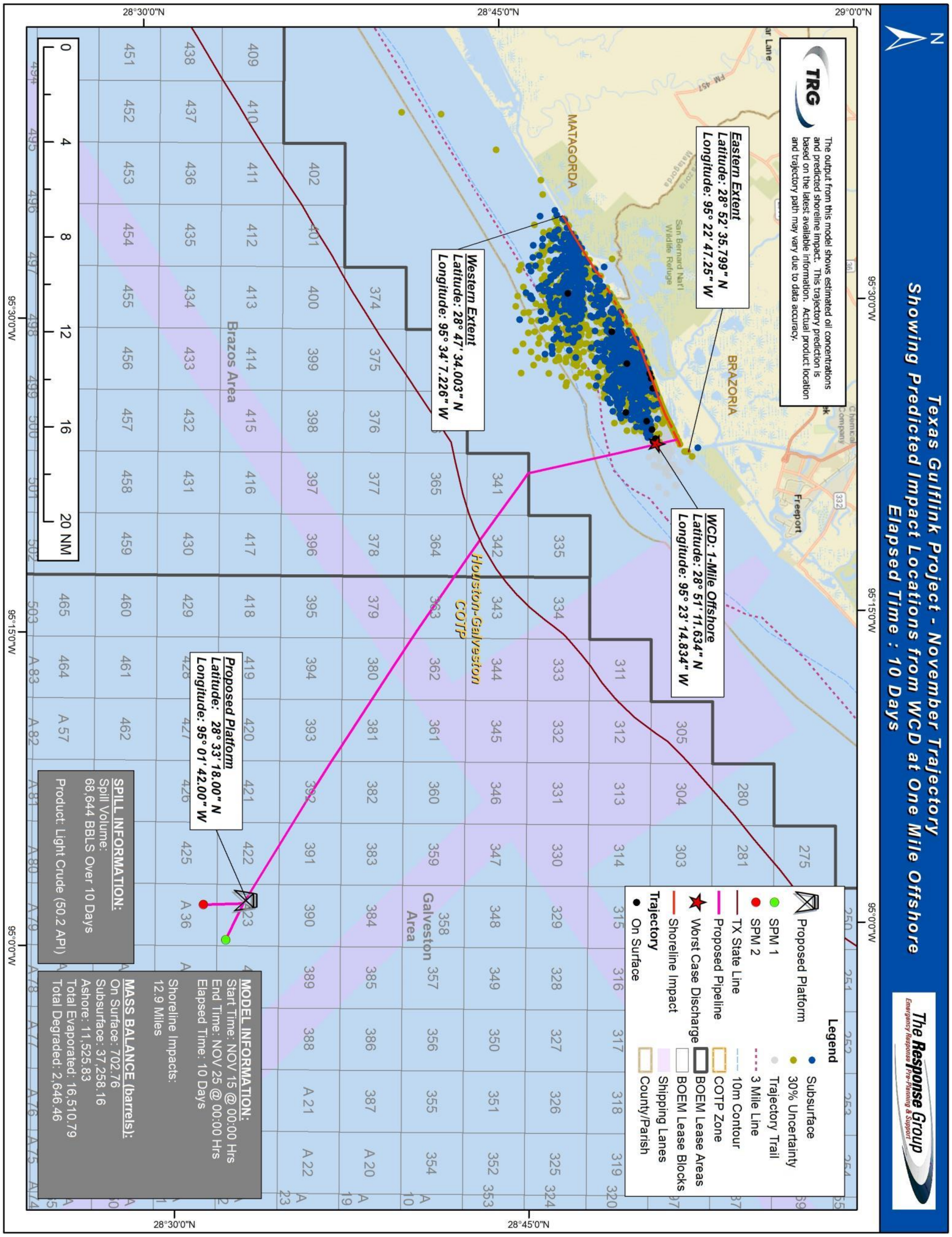
Brazoria County encompasses the predicted shoreline impact for the August model. The model estimates approximately 8,300 barrels are predicted to impact 1.2 miles of shoreline by day 10.



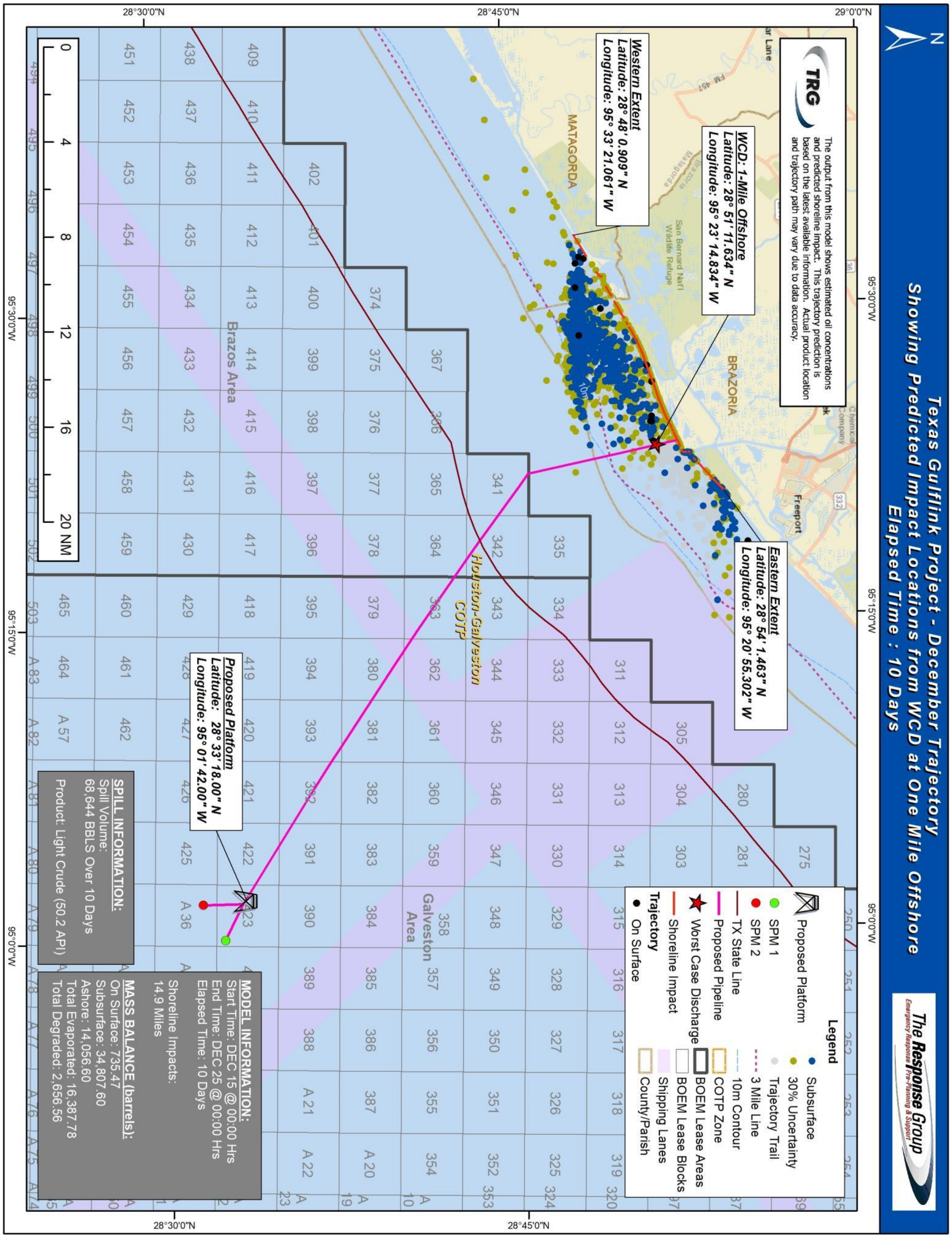
Predicted shoreline impact for the September model affects Matagorda and Brazoria counties. The model estimates approximately 11,300 barrels are predicted to impact 10.2 miles of shoreline by day 10.



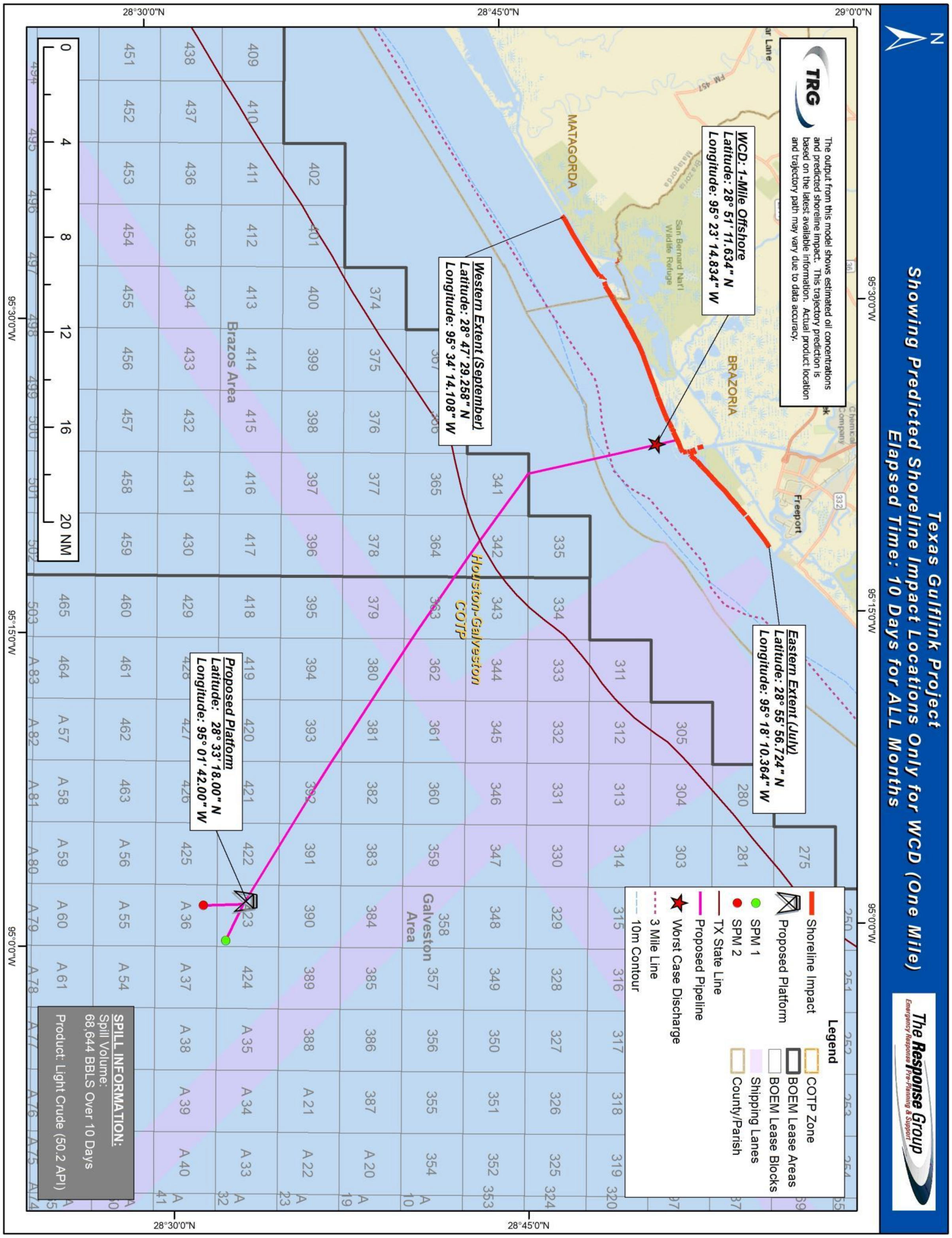
Brazoria County encompasses the predicted shoreline impact for the October model. The model estimates approximately 10,300 barrels are predicted to impact 10.2 miles of shoreline by day 10.



Predicted shoreline impact for the November model affects Matagorda and Brazoria counties. The model estimates approximately 11,500 barrels are predicted to impact 12.9 miles of shoreline by day 10.



Predicted shoreline impact for the December model affects Matagorda and Brazoria counties. The model estimates approximately 14,000 barrels are predicted to impact 14.9 miles of shoreline.



The model estimates approximately 20.3 miles of shoreline could receive impact across all months.

MODEL PARAMETERS: INLAND

MODEL BACKGROUND

The trajectory models in this study were created using RPS ASA's OILMAP trajectory modeling software. The software allows us to create multiple deterministic models, based on defined winds and currents. The results provide the potential outcome of a release from the WCD locations of a single crude during monthly averaged periods. For these models, average winds, outgoing tides, and 75 degree water temperatures were used. The results of the trajectory models presented herein assumes no response efforts are employed and therefore no oil would be contained, recovered, or diverted. However, in the actual situation of an unanticipated discharge, highly-trained tactical response teams would be mobilized immediately to start mitigation efforts.

WINDS

The winds used in the models were derived from both pilot charts and NOAA National Centers for Environmental Information.

CURRENTS

Currents used in the models are averages based on an outgoing tide, and the ICWW current speeds were defined at one knot; tidal, Brazos River at two knots; tidal, and Jones Creek at 0.1 knots; tidal.

Inland Scenarios:

1) 42" pipeline to the offshore platform crossing the Intracoastal Waterway (ICWW); 11,501 barrels

5 minute shutdown time = 7,083 Barrels; volume between the valves = 4,418

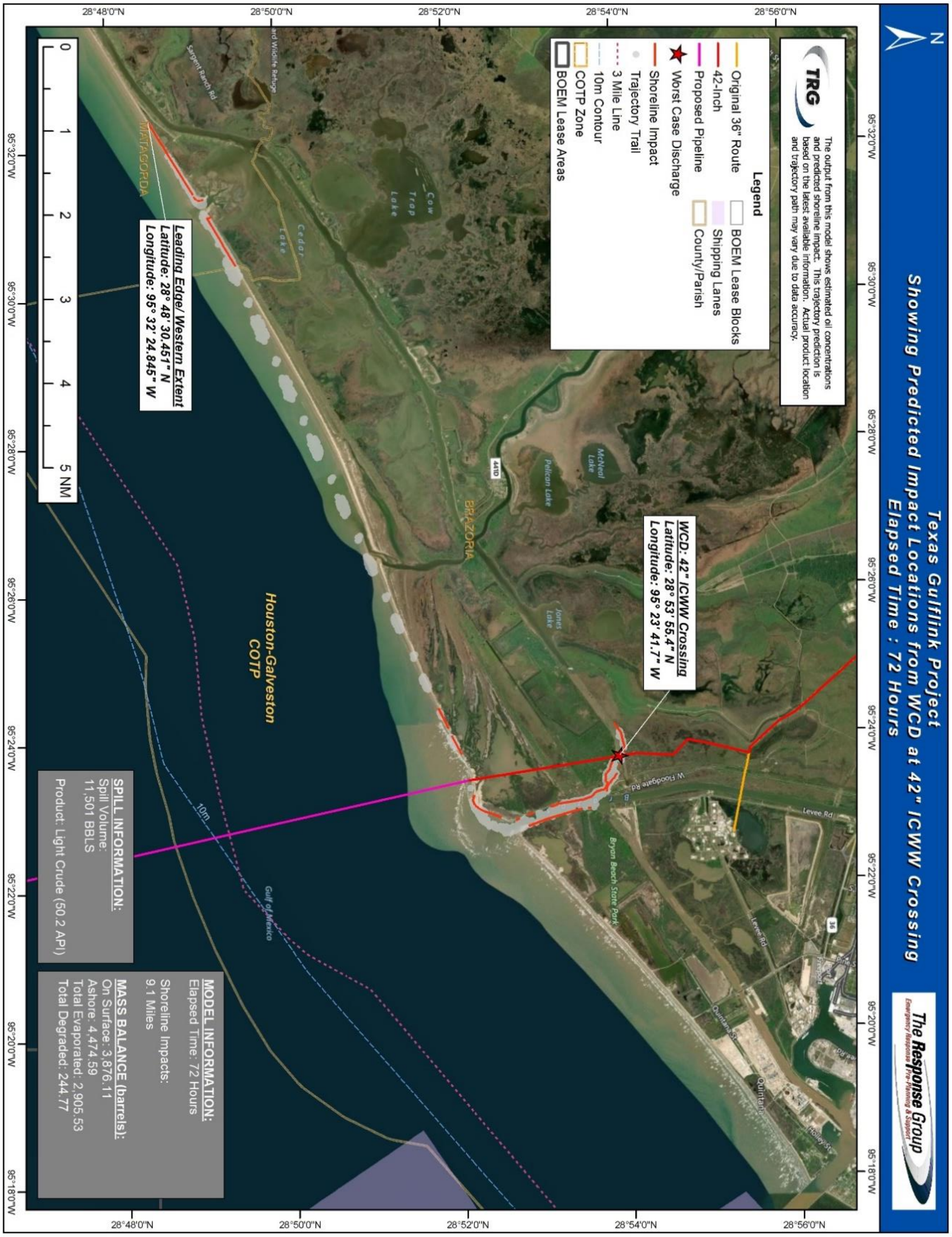
2) 36" pipeline from DOE SPR crossing the Brazos River Diversion; 11,248 Barrels

5 minute shutdown time = 7,083 Barrels; volume between the valves = 4,165

3) 42" pipeline crossing at Jones Creek; 9,450 Barrels

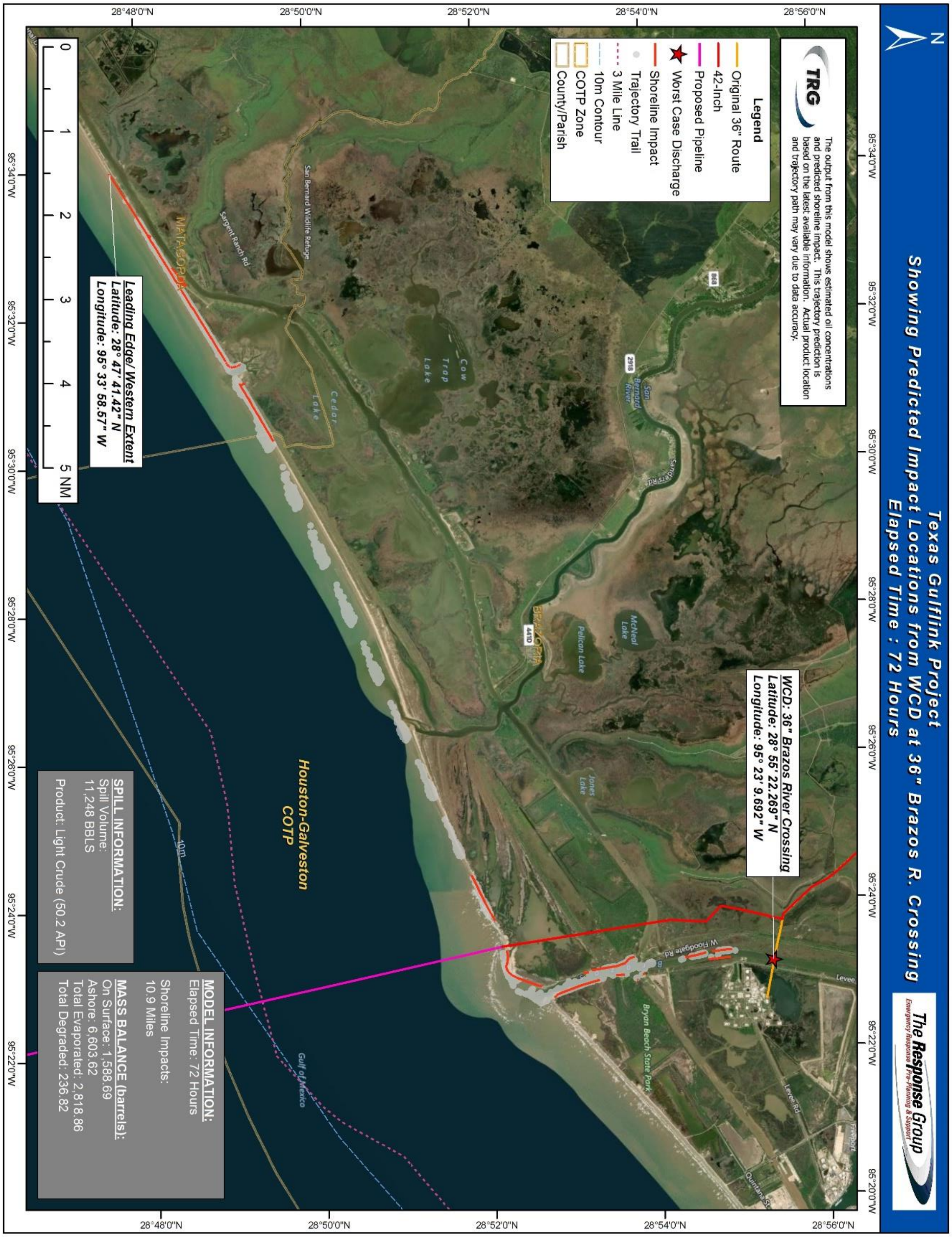
5 minute shutdown time = 7,083 Barrels; volume between the valves = 2,367

Summary – Intracoastal Waterway (ICWW) Crossing



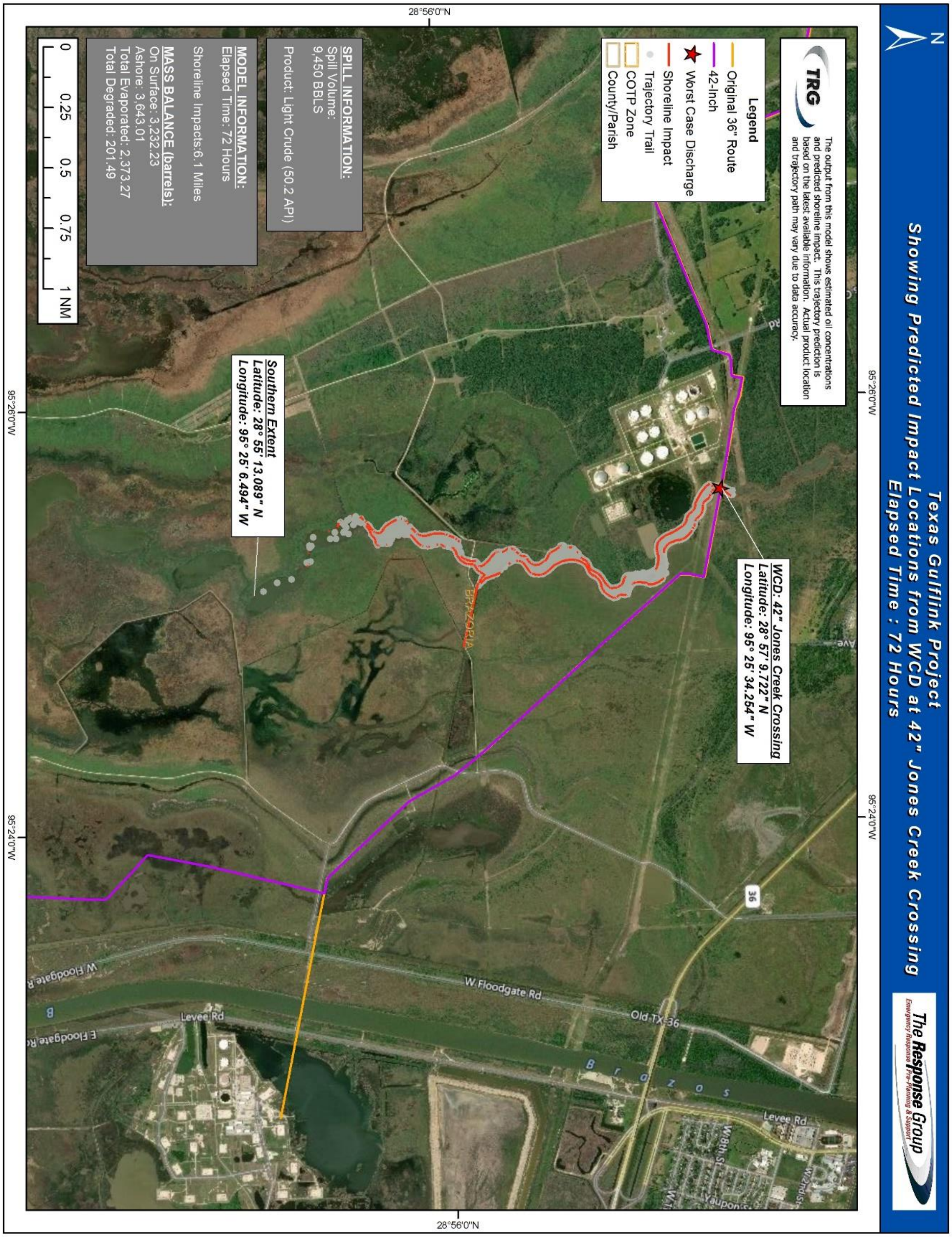
The ICWW model estimates approximately 4,500 barrels would be stranded along 9.1 miles of shoreline over 72 hours.

SUMMARY – BRAZOS RIVER CROSSING



The Brazos River model estimates approximately 6,600 barrels would be stranded along 10.9 miles of shoreline over 72 hours.

SUMMARY – JONES CREEK CROSSING



The Jones Creek model estimates approximately 3,650 barrels would be stranded along 6.1 miles of shoreline over 72 hours.

REFERENCES

Hybrid Coordinate Ocean Model
http://hycom.org

NOAA Office of Response and Restoration Environmental Sensitivity Index (ESI) Maps;
https://response.restoration.noaa.gov/maps-and-spatial-data/environmental-sensitivity-index-esi-maps.html

The Texas General Land Office Oil Spill Toolkit;
http://www.glo.texas.gov/coast/oil-spill/toolkit/index.html

Exchange Flow of Oil and Seawater in Leaking Subsea Pipelines, by Peter Carr, EPConsult LLC, Houston

Volume II
Appendix K

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TGLP Oil Spill Consequence Report for Inland Worst-Case Discharge

TEXAS GULFLINK PROJECT
OIL SPILL CONSEQUENCE REPORT
FOR INLAND
WORST CASE DISCHARGES

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BACKGROUND

INTRODUCTION AND SCOPE

The intent of this document is to define the environmentally and socio-economically sensitive and at-risk sites and species in the event of a release from two Worst Case Discharge (WCD) locations along the proposed pipeline associated with the Texas Gulflink Project Platform which is located approximately 33 miles Southeast of Freeport, TX. To determine the potential receptors to an incident, trajectory models have been generated for three defined worst case discharge locations on the inland side. The trajectories were developed based on an outgoing tide to determine the largest impact to shoreline, waterways, and access to beachfront. Each model run was analyzed to determine potential environmental and/or socioeconomic impacts.

SITES AND SURROUNDING AREA DESCRIPTION

The proposed platform is located at 28° 33' 18.00" N, 95° 01' 42.00" W, approximately 30 miles offshore of Matagorda Island, Texas.

Areas surrounding the proposed sites include Brazoria and Matagorda counties, (as seen in Figure 1). State and federal lands include: San Bernard WMA and Peach Point WMA-Bryan Beach.

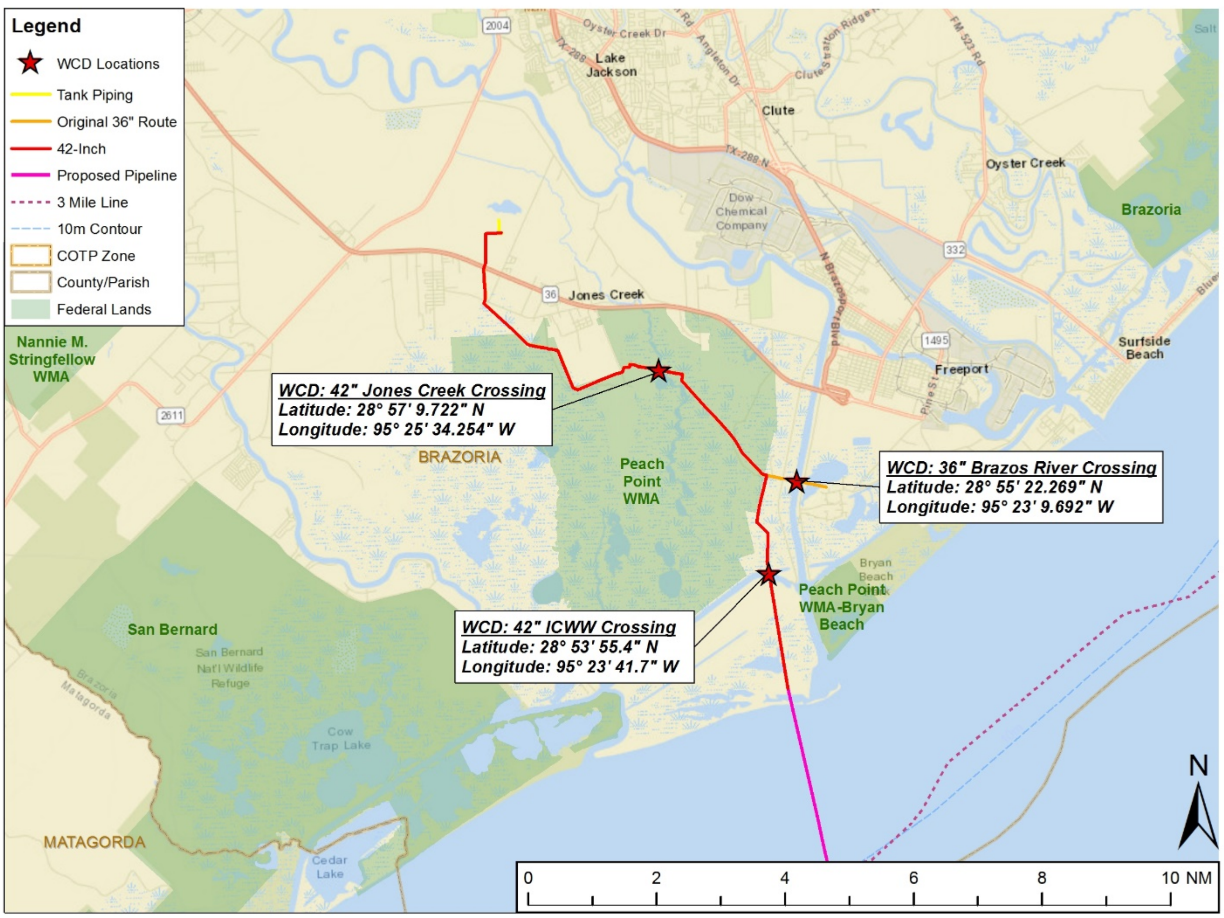


Figure 1 – Overview of area surrounding the three identified inland Worst Case Discharge Locations

BACKGROUND

WORST CASE DISCHARGE VOLUMES

The Worst Case Discharges along the pipeline have been calculated as the volume contained in the Horizontal Direction Drill (HDD) portion of the pipeline as well as the 5-minute shutdown time in order to generate spill trajectories. This aids in determination of the fates and effects of oil, and thereby allows us to understand the potentially impacted environmental and socio-economically sensitive areas defined in this document.

Pumping rate through the pipeline is 60K Barrels per hour. With an estimated shutdown time of 5 minutes, it is expected that 7,083 barrels of oil plus the volume in the line between valves will escape the inland Worst Case Discharge locations described in this document.

The Inland Worst Case Discharges are presented below:

36” pipeline from DOE SPR crossing the Brazos River Diversion; 9,412 Barrels

5 minute shutdown time = 5,000 Barrels; volume of the HDD = 4,412

42” pipeline to the offshore platform crossing the Intracoastal Waterway (ICWW); 15,602 barrels

5 minute shutdown time = 7,083 Barrels; volume of the HDD = 8,519

42” pipeline crossing at Jones Creek; 9,450 Barrels

5 minute shutdown time = 7,083 Barrels; volume of the HDD = 2,367

BACKGROUND

OIL FATES, A DESCRIPTION (IPIECA, OIL SPILL REPONSE PROJECT)

Evaporation

When released on the sea or shore, evaporation of hydrocarbons into the atmosphere will begin immediately, influenced by ambient temperature and air movement. This process progressively increases the viscosity of the spilled oil, but also reduces the volume and acute toxicity of the remaining oil. If the oil remains at the surface for many hours or days, this weathering process can leave a sticky residue with a relatively low toxicity. The proportion of oil remaining can vary from almost none to almost all of the oil originally spilled. For example, 10 tonnes of gasoline spilled into a tropical sea on a calm summer day (25°C) would evaporate completely in less than three hours, and would take only six hours to evaporate in an Arctic sea on a calm winter day (5°C); however, in the same conditions, a heavy fuel oil (e.g. Bunker C) would have lost only 20% and 15% of its volume, respectively, to evaporation after four days (source: NOAA, 2015).

Spreading and movement

If an oil is spilled onto the sea surface it will spread, even without any movement due to tides or winds. The rate of spread depends on the oil's pour point and viscosity: light oils will spread very quickly, at any sea temperature, but heavy oils will spread more slowly and remain thicker for longer, particularly in colder seas where this can also reduce the rate of dispersion. Any surface life or animals that need to come to the surface to breathe will be vulnerable to an oil slick, and the speed and direction of winds and tides will influence how far and wide the slick may spread. As most oil spread and move they also rapidly start to fragment, resulting in patchiness and the formation of numerous slicks. The oil thickness often becomes very uneven, with scattered areas of thicker oil separated by large areas of very thin oil (sheen) or clear water.

Dissolution

While most hydrocarbons have such a low solubility in water (including seawater) that we can effectively define them as insoluble, some of the smaller aromatic hydrocarbons, such as benzene and toluene, are relatively soluble. Thus, when oil is spilled into the sea, a small proportion dissolves; the amount and rate of dissolution depends on the oil composition and viscosity. This water soluble fraction has a disproportionate impact on marine organisms, being more bioavailable than other hydrocarbons and often more acutely toxic. High Concentrations of these hydrocarbons are generally limited to the water in the immediate vicinity of the spilled oil, and rapid dilution occurs both vertically and laterally. Biodegradation of water soluble hydrocarbons is generally rapid.

Dispersion

Wave action, or other agitation of the oil on (or in) the water, will result in the formation of oil droplets that become mixed into the water column; the greater the agitation the greater the mixing potential. The majority of oil from most spills, whether spilled onto the sea surface, released subsea or deposited onto the shoreline, is eventually dispersed. Larger droplets mixed into the water column quickly resurface, but small droplets are less buoyant and do not resurface; they are mixed horizontally and vertically in the water column. The extent and depth of mixing depends on wave action and water currents. This process can potentially lead to subsurface marine life being exposed to contamination. However, as with the dissolved hydrocarbons, the Concentrations of dispersed oil are highest in the immediate vicinity of the release, be it a surface slick or subsurface rising plume, and reduce rapidly as the oil is dispersed further away from the source. In the case of surface slicks, the buoyancy of the oil droplets means that vertical mixing into deeper water is slower than lateral mixing, and elevated Concentrations are generally limited to the upper few meters. Dispersed oil droplets have a large surface area and this facilitates biodegradation by microbes. The effectiveness of oil droplet biodegradation is a key benefit of using chemical dispersants to enhance the natural dispersion process.

Emulsification

Larger droplets of dispersed oil will quickly resurface and can trap seawater droplets within the surface slick to form a water-in-oil emulsion. Most oils will therefore progressively incorporate water when they are mixed in turbulent conditions (i.e. in moderate or rough seas). The greater the mixing effect, the more water is incorporated into the emulsion, hence the volume of the emulsion increases; in some circumstances the volume of a water-in-oil emulsion can be up to five times greater than the volume of oil originally spilled.

Emulsions may be stable or unstable, and can have very different physical characteristics to their parent oil. Stable emulsions typically have a high water content (sometimes greater than 70%) and are usually highly viscous. They can remain stable for several weeks, and are colloquially referred to a ‘chocolate mousse’ (or sometimes just ‘mousse’) due to their consistency and typically reddish-brown color. The formation of a stable mousse can greatly reduce the rate of dispersion and other fate processes. In calm, warm conditions, e.g. after landing on a beach, a mousse may break down to its constituent oil and water, but some emulsions are highly persistent. An unstable emulsion may decompose after several days, or may persist for as little as 24 hours. Unstable emulsions usually retain the color of the original oil, i.e. either dark brown or black.

Sedimentation

The fate and effects of dispersed oil are greatly influenced by the amount of suspended solids (fine sediments and other particles) present in the water column. Dispersed oil droplets can bind to suspended solids and change their physical characteristics. Chemically-dispersed droplets may be less likely to bind than physically-dispersed droplets until the dispersant is biodegraded. Deposition of these suspended solids to the seabed can occur, where they may be incorporated into muddy seabed areas with active sedimentation or more widely distributed as a loose aggregation (floc) of oiled particles, or a combination of both. In worst-case situations, where Concentrations of oil droplets and suspended sediments are both high, heavy deposition of contaminated particles could result in severely oiled seabed sediments, where they may persist for years and potentially have long-term effects. Fortunately, such conditions are unusual and most dispersed oil is more widely distributed and biodegraded before it can become incorporated into seabed sediments. However, the presence of loose flocs of oiled particles (i.e.

flocculent material formed by aggregation of suspended oil and sediment particles) can result in filter-feeding animals on the seabed being exposed to elevated Concentrations of hydrocarbons.

Sinking

Sinking is often discussed along with sedimentation (described above), but from an ecological perspective it is very different because it does not produce plumes or flocs of oiled particles. Sinking occurs if the spilled oil is denser than seawater, and can result in very persistent accumulations that lie on the seabed and sometimes become buried. The impacted area of seabed is typically smaller than that affected by sedimentation of dispersed oil, but sunken oil can cause long-term smothering and loss of habitat. Not many oils are this dense, even after much weathering. However, a few very dense oils, including Group 5 oils and some others that can weather to a high density, can sink in some circumstances. For example, wind-blown sand can sometimes be deposited on floating oil causing it to sink, and layers of fresh water on the sea surface near rivers or ice floes can reduce the density of the seawater, again allowing the oil to sink. Burnt residues of oil can be heavier than seawater and therefore prone to sinking. While such circumstances are not commonplace, spilled oil often comes ashore on sand beaches and mixes with sand in the surf zone, resulting in the formation of tar balls and tar mats that can sink in the shallow subtidal zone just off the beach. Again, these may be persistent and provide a potential long-term (chronic) source of contamination, though the toxicity of the oil is largely trapped inside the tar matrix so it has very limited bioavailability.

Shoreline stranding

The processes described above progressively reduce the quantity of oil in a surface slick, so it is possible for an offshore oil spill to result in no oil, or only small amounts of oil, reaching the shore. However, most moderate or large spills result in at least some shoreline oiling, which may then impact the full range of habitats and species present below the high tide level, and sometimes above it.

Natural physical and chemical processes will continue to weather the oil and gradually remove it, but the speed of removal varies greatly and depends on a range of factors. Persistence will be greater in places that are sheltered from wave action and water movement, but only small amounts of wave action are required to remove oil. Residues that remain for more than a year or two are generally only found in very sheltered situations or in locations where it has been deeply buried. For more information on the fate of shoreline oil see the IPIECA-IOGP Good Practice Guide on the impacts of oil spills on shorelines (IPIECA-IOGP, 2015a)

Photo-oxidation

Hydrocarbons exposed to ultraviolet (UV) light can be photochemically oxidized to form other compounds. This is often a minor component of the weathering process but PAHs are particularly sensitive. Laboratory studies of some compounds have found that the resulting products can be more toxic than the parent compounds, largely because they are more soluble in water. This increased bioavailability also increases their potential for biodegradation. The extent to which UV light has any effect on whole oils and on overall toxicity in the natural environment is the subject of ongoing investigations.

Biodegradation

Marine bacteria have evolved to produce enzymes that allow them to utilize hydrocarbons from crude oil as a food source. By metabolizing hydrocarbons they grow and multiply, and in turn become a food source for other organisms. It is through this natural process that the majority of the oil from a spill is ultimately biodegraded, and the energy and materials contained within it are returned to the food chain. Degradation requires adequate oxygen, nutrients and trace elements and its rate is primarily dependent on the ratio of surface area to volume of the oil, i.e. finely dispersed droplets will degrade rapidly while a thick slick or a patch of oil on a shoreline will degrade slowly. Large hydrocarbon molecules are not readily biodegraded and can persist for many years; these include some PAHs that are potentially toxic but have extremely low solubility in water and therefore have very limited biological availability. Some of the largest hydrocarbons, such as asphaltenes (used for road asphalt), are so resistant to biodegradation that a patch of tar could remain for hundreds of years but is effectively inert. Bacteria that can degrade oil are present everywhere, though not always in large densities, so there can be a time lag before they have multiplied enough that their activity becomes appreciable. Biodegradation rates can be limited by the Concentrations of available nutrients that the microbes require to multiply and grow. Lack of oxygen can also be a limiting factor in some situations, particularly within muddy sediments. Cold temperatures reduce the rate of biodegradation, but not necessarily to a great extent. Recent studies of deep water situations in the Gulf of Mexico show that the bacteria are adapted to the stable 5°C conditions and can degrade oil quickly if it is adequately dispersed.

Note*

The trajectory models presented in this document will take into account the following oil fates:

- Evaporation
- Spreading and movement
- Dispersion
- Shoreline stranding

BACKGROUND

TYPICAL MARSH AND BEACH PROFILES

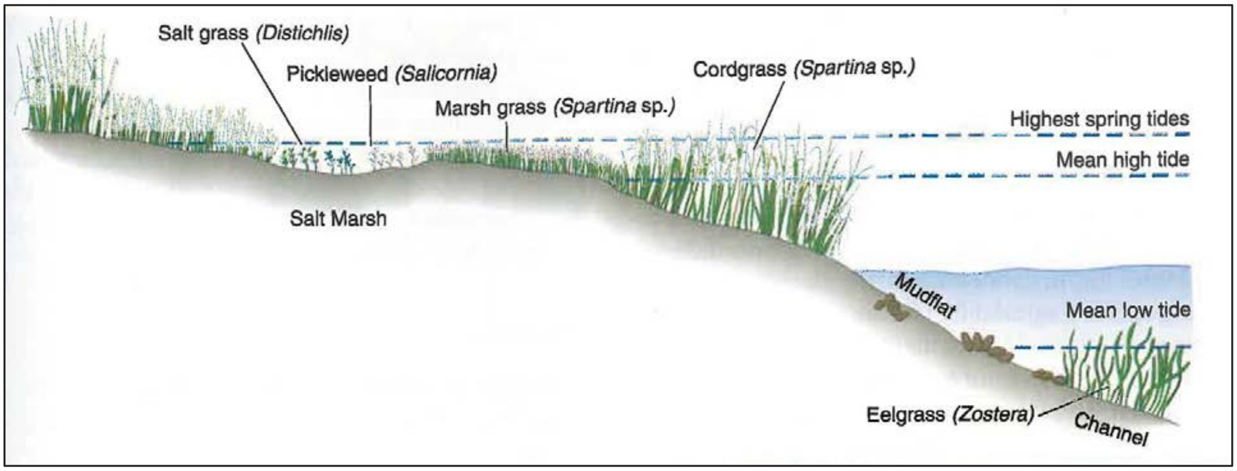


Figure 2 – Overview of a typical Marsh Profile. The potentially impacted environmental and socio-economic resources presented in this document range from the channel/mean low tide to marsh grass, as presented above.

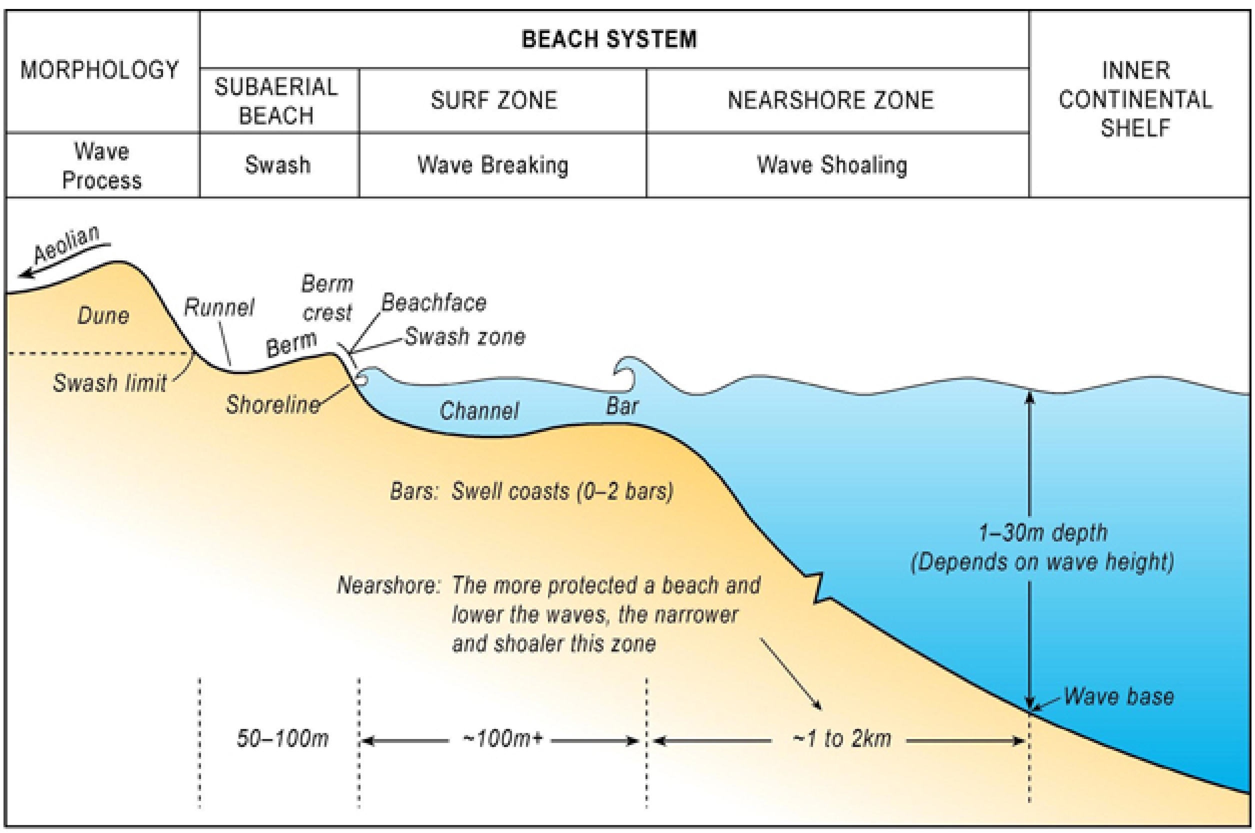


Figure 3 – Overview of a typical Beach Profile. The potentially impacted environmental and socio-economic resources presented in this document range from the Nearshore Zone to the base of the Dunes, as presented above.

BACKGROUND

TEXAS SALT MARSHES:

Salt marshes line the landward side of Texas' inner bays with cordgrass, saltgrass and other plants able to live in brackish water. Animals here must also tolerate the constant changes in water level and saltiness brought to the salt marsh by tides and freshwater inflow. These marshes form when salt-tolerant plants take root on mud flats around the edges of bays. The plants slow the flow of water during hightide, allowing sediments to settle out and raising the level of the land so more plants can grow.

Marshes act as biological filters where pollutants from freshwater runoff can settle out before reaching the Gulf. Salt marshes are a vital part of the coastal ecosystem. Together with wetlands, marshes act as biological filters where pollutants from freshwater runoff can settle out before reaching the Gulf. Decaying vegetation from the marsh provides adjoining bays with food from many small marine animals. These, in turn, are food for fish, mammals and birds. Marshes also serve as spawning grounds and nursery for marine animals including blue crabs and red drum.

BACKGROUND

BEACH MORPHOLOGY FROM GALVESTON TO MATAGORDA ISLAND:

The open sandy beach is a habitat that many people are familiar with. The beach extends from the Gulf shoreline to the beginning of the fore dune, which is the part of the dune that faces the Gulf. No plants grow on the beach primarily from the frequent inundation of this area by salty seawater. Plant material, primarily Sargassum seaweed, does wash up onto the beach during certain seasons. This and other debris attracts the attention of foraging birds.

Other bird species such as snowy plovers, sanderlings, and willets regularly forage at the water's edge. They search for small invertebrates that live in the wet sand. While the birds are looking for their next meal as they scavenge along the beach, humans enjoy beachcombing for pleasure - where we hope to discover treasures that the Gulf waters have washed up on the beach.

Dunes are one the most important physical structures on a barrier island. They form at the back edge of the beach, just beyond the place where the Gulf waters regularly reach. The dune is an accumulation of drifting and blowing sand and is partially held in place by vegetation. All the plants growing in this area face harsh conditions: low nutrient sandy soil, a scarcity of fresh water, and salt laden breezes that deposit salt on exposed plant tissues. The plants that do grow in this area, such as panicum, morning glory, and sea purslane, have characteristics that help them to tolerate the rough conditions. The roots of a number of common dune plant species grow deep and spread themselves wide in order to collect the sparse nutrients and water. This network of plant roots in turn helps to stabilize the dune and allows it to grow larger.

Beach dunes on barrier islands mitigate the effects of unusually high tides and storm surges. They absorb energy delivered by stormy weather and unusually high water. They can prevent salt water from reaching areas behind the dune and even when they are overtopped the dunes lessen the physical impact a rough storm can have on a barrier island. The dunes also function as a sand reservoir that will replenish some of the sand that is stripped away from the beach during a storm. This will decrease the size of the dunes but they will begin the slow but steady process of rebuilding once a disturbance has passed and the beach has attained a new equilibrium state.

Just as dunes serves as a buffer for a barrier island, the barrier island itself helps to protect the mainland coast from bearing the brunt of the destructive energy delivered by violent storms that sweep in from the Gulf.

TRAJECTORY RESULTS AND REVIEW

FULL EXTENT OF SHORELINE IMPACT – WCD = THREE INLAND LOCATIONS

The full extent of shoreline impact is provided below. Based on the trajectory models for the three WCD locations, the predicted length of shoreline impact totals (cumulatively, for all 12 months) 16.8 miles of shoreline, with most of the impacts attributed to the Brazos River. Primary impacts are predicted to be the beach, Brazos River, and Peach Point WMA, Jones Creek, and associated environmental and socio-economic resources, to be described later in this document.

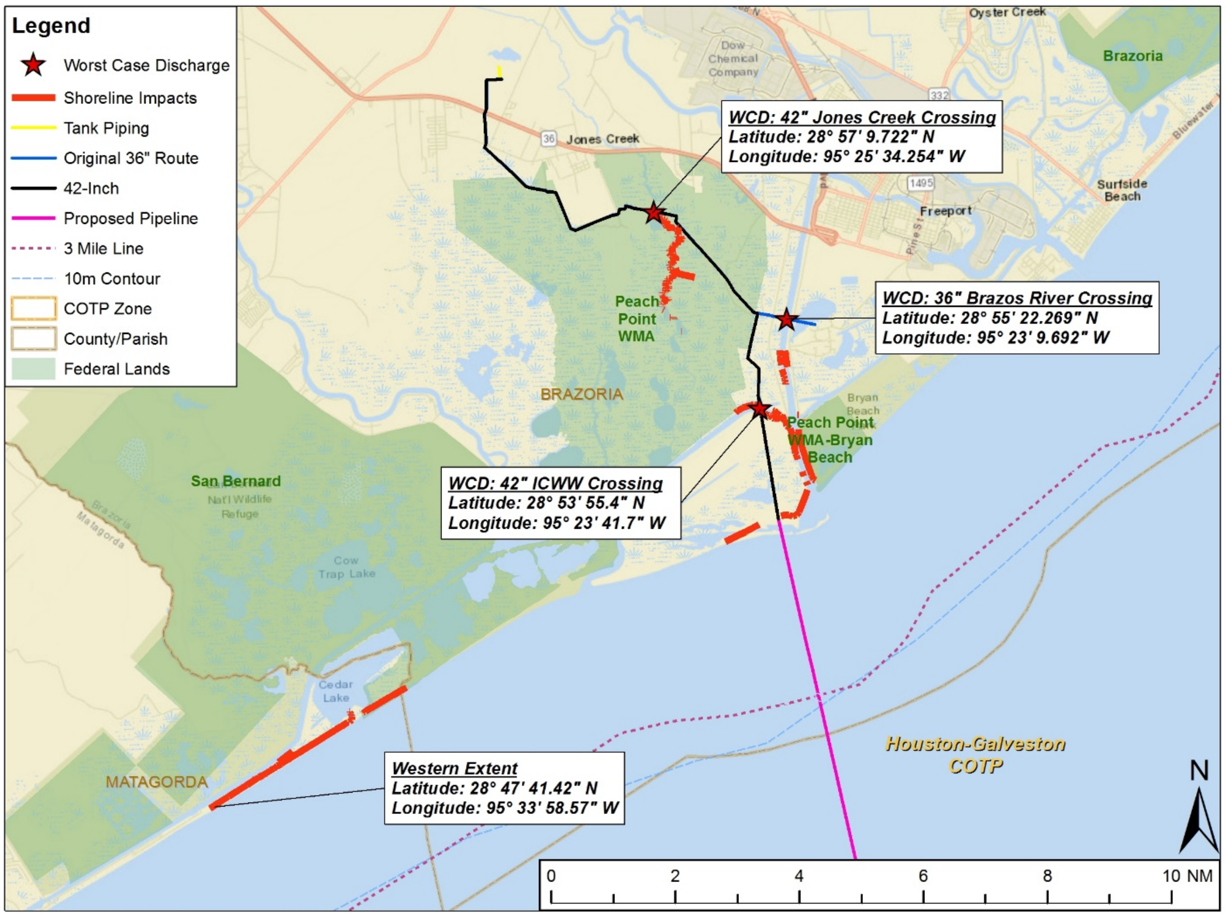


Figure 4 – Trajectory Map depicting full shoreline impact at 3 days' time based on Worst Case Discharge from the three WCD locations (outgoing tides).

ENVIRONMENTAL AND SOCIOECONOMIC RESOURCES AT RISK

ENVIRONMENTAL AND SOCIO-ECONOMIC RESOURCES AT RISK

In order to determine potential environmental impacts, an expansive data search was conducted to identify the environmentally and socio-economically sensitive sites. The sources of data used in reference for this search was from the Texas General Land Office (TGLO) Toolkit, as well as the National Oceanic and Atmospheric Administration Environmental Sensitivity Index (NOAA's ESI) Mapping data. Based on the inland spill trajectories, two primary areas of focus (North to South) have been listed and described for potential impacts and consequences:

(1) Peach Point (Justin Hurst) WMA-Bryan Beach and Brazos River
(2) San Bernard WMA

*Note:

(1) For Environmental Resources at Risk, NOAA's ESI Maps have been provided, and referenced on the attached index map for each Area at Risk mentioned above. For a more in-depth look into the sensitivities and habitat for each area, please see the TGLO Toolkit website, in the references section below.

(2) For Socio-Economic Resources at Risk, the associated map and relevant data points have been provided on a single map for each Area at Risk.

1.a) Peach Point (Justin Hurst) WMA-Bryan Beach and Brazos River; Environmental

TGLO Protection Sites: 99-A, 99-B, 99-C, 98-DD
Threatened or endangered species in this area:

TYPE	SPECIES	STATUS	CONCENTRATION
Bird	Peregrine Falcon	Threatened	N/A
Bird	Piping Plover	Threatened	Individuals
Bird	Reddish Egret	Threatened	Present
Bird	Bald Eagle	Threatened	Nest
Bird	Wood Stork	Threatened	N/A
Marine Mammal	West Indian Manatee	Endangered	Very rare
Reptile	Kemp's Ridley Sea Turtle	Endangered	Common
Reptile	Green Sea Turtle	Threatened	Occasional
Reptile	Hawksbill Sea Turtle	Endangered	Occasional
Reptile	Loggerhead Sea Turtle	Threatened	Occasional

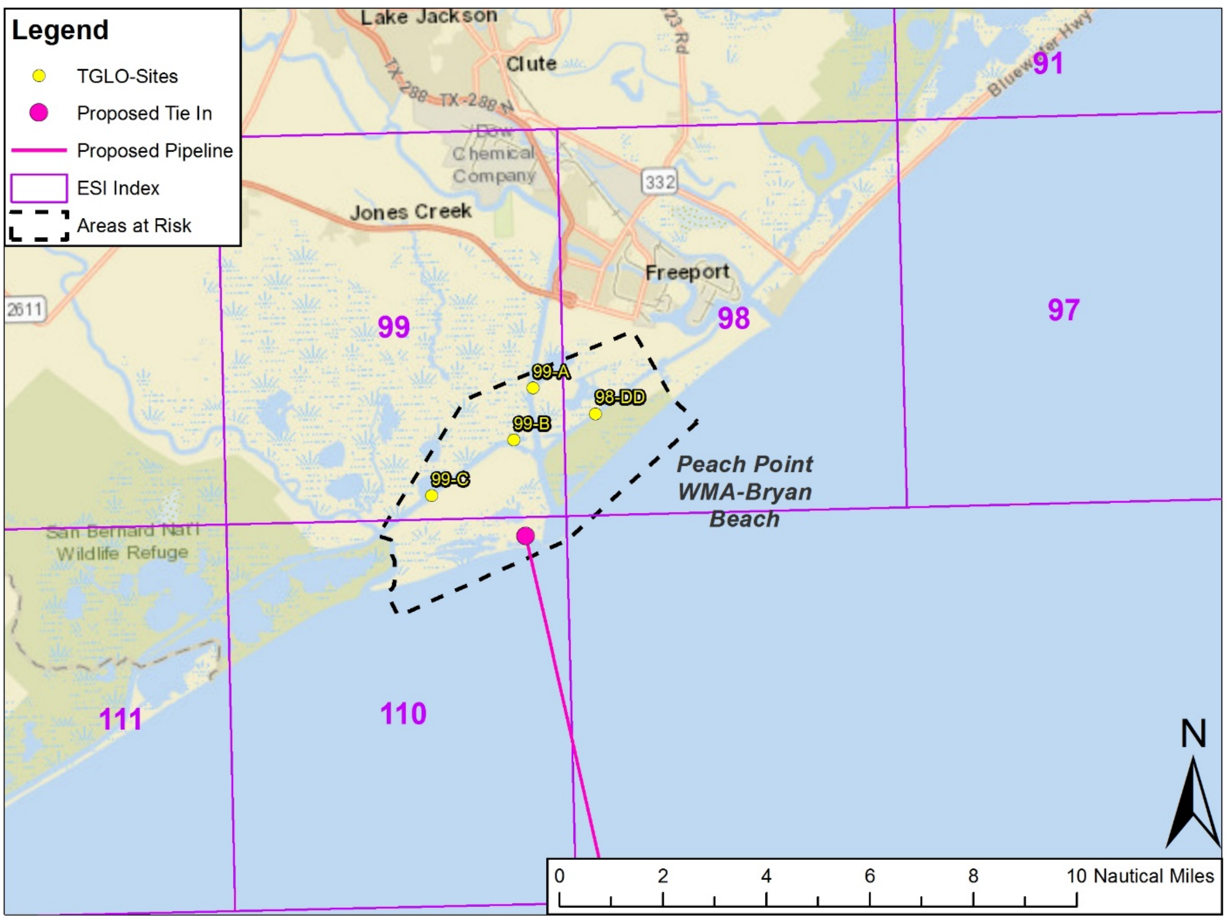
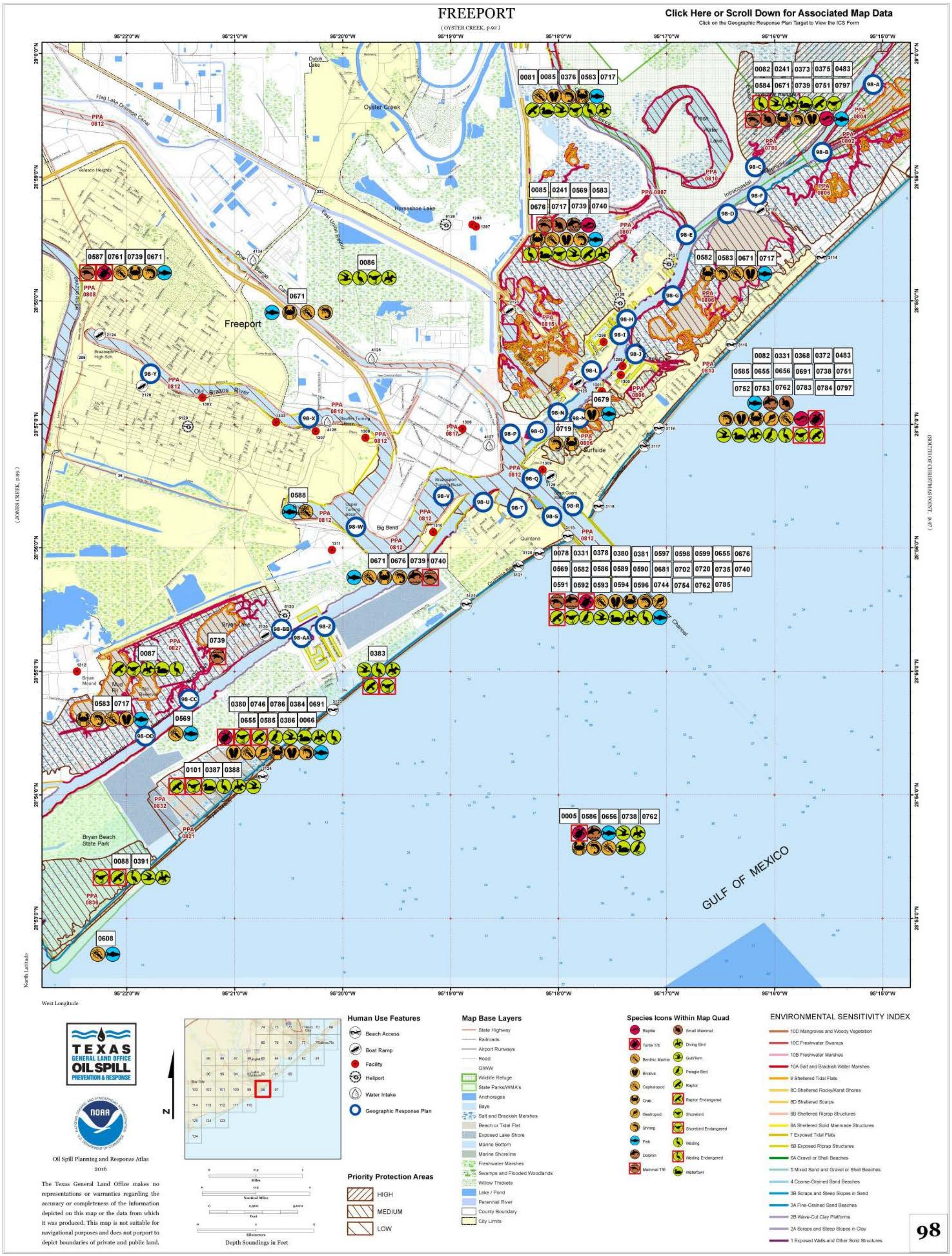
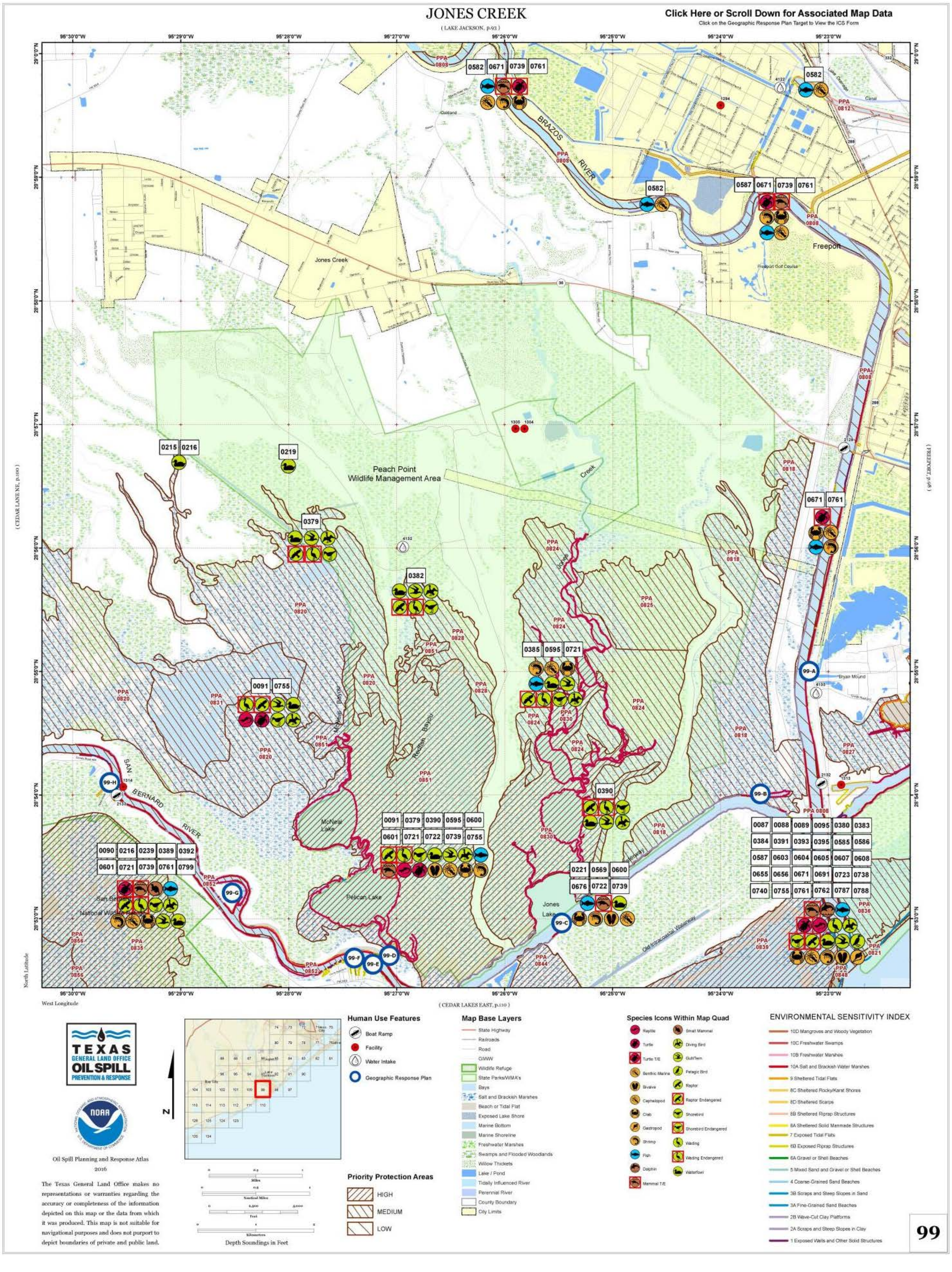


Figure 5 – ESI Index Overview and TGLO Sites of Peach Point (Justin Hurst) WMA-Bryan Beach; Predicted Impact Locations


FREEPORT
(OYSTER CREEK, p.92)
Click Here or Scroll Down for Associated Map Data
Click on the Geographic Response Plan Target to View the ICS Form
Freeport
Oyster Creek
Horseshoe Lake
Old Brazos River
Big Bend
Bryan Lake
Surfside
Quintana
Bryan Beach State Park
GULF OF MEXICO
North Latitude
West Longitude
Oil Spill Planning and Response Atlas
2016
The Texas General Land Office makes no representations or warranties regarding the accuracy or completeness of the information depicted on this map or the data from which it was produced. This map is not suitable for navigational purposes and does not purport to depict boundaries of private and public land.
Depth Soundings in Feet
Human Use Features
Beach Access
Boat Ramp
Facility
Heliport
Water Intake
Geographic Response Plan
Priority Protection Areas
HIGH
MEDIUM
LOW
Map Base Layers
Species Icons Within Map Quad
ENVIRONMENTAL SENSITIVITY INDEX
98



JONES CREEK
(LAKE JACKSON, p.93)
Click Here or Scroll Down for Associated Map Data
Click on the Geographic Response Plan Target to View the ICS Form
Peach Point
Wildlife Management Area
Jones Creek
Freeport
BRAZOS RIVER
SAN BERNARD RIVER
McNeal Lake
Pelican Lake
Jones Lake
Old Intracoastal Waterway
(CEDAR LAKES EAST, p.110)
(CEDAR LANE NE, p.100)
(FREEPORT, p.98)
West Longitude
North Latitude
Human Use Features
Boat Ramp
Facility
Water Intake
Geographic Response Plan
Map Base Layers
State Highway
Railroads
Road
GIWW
Wildlife Refuge
State Parks/WMA's
Bays
Salt and Brackish Marshes
Beach or Tidal Flat
Exposed Lake Shore
Marine Bottom
Marine Shoreline
Freshwater Marshes
Swamps and Flooded Woodlands
Willow Thickets
Lake / Pond
Tidally Influenced River
Perennial River
County Boundary
City Limits
Priority Protection Areas
HIGH
MEDIUM
LOW
Species Icons Within Map Quad
ENVIRONMENTAL SENSITIVITY INDEX
TEXAS GENERAL LAND OFFICE OIL SPILL PREVENTION & RESPONSE
Oil Spill Planning and Response Atlas
2016
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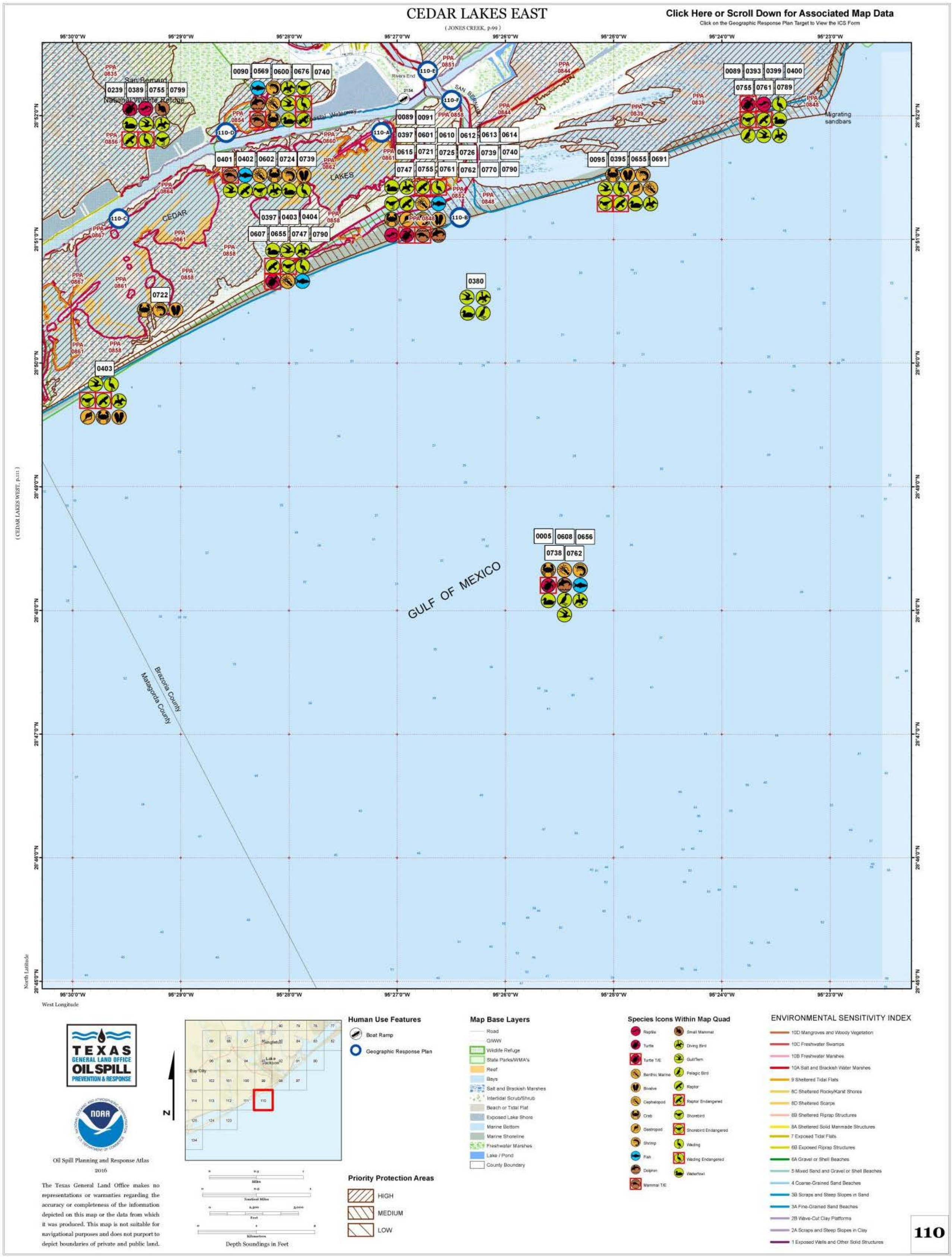
Depth Soundings in Feet
99


CEDAR LAKES EAST
(JONES CREEK, p.99)
Click Here or Scroll Down for Associated Map Data
GULF OF MEXICO
CEDAR
LAKES
San Bernard National Wildlife Refuge
Migrating sandbars
Brazoria County
Matagorda County
95°30'0"W
95°29'0"W
95°28'0"W
95°27'0"W
95°26'0"W
95°25'0"W
95°24'0"W
95°23'0"W
West Longitude
North Latitude
Human Use Features
Boat Ramp
Geographic Response Plan
Priority Protection Areas
HIGH
MEDIUM
LOW
Map Base Layers
Road
GIWW
Wildlife Refuge
State Parks/WMA's
Reef
Bays
Salt and Brackish Marshes
Intertidal Scrub/Shrub
Beach or Tidal Flat
Exposed Lake Shore
Marine Bottom
Marine Shoreline
Freshwater Marshes
Lake / Pond
County Boundary
Species Icons Within Map Quad
Reptile
Turtle
Turtle T/E
Benthic Marine
Bivalve
Cephalopod
Crab
Gastropod
Shrimp
Fish
Dolphin
Mammal T/E
Small Mammal
Diving Bird
Gull/Tern
Pelagic Bird
Raptor
Raptor Endangered
Shorebird
Shorebird Endangered
Wading
Wading Endangered
Waterfowl
ENVIRONMENTAL SENSITIVITY INDEX
10D Mangroves and Woody Vegetation
10C Freshwater Swamps
10B Freshwater Marshes
10A Salt and Brackish Water Marshes
9 Sheltered Tidal Flats
8C Sheltered Rocky/Karst Shores
8D Sheltered Scarps
8B Sheltered Riprap Structures
8A Sheltered Solid Manmade Structures
7 Exposed Tidal Flats
6B Exposed Riprap Structures
6A Gravel or Shell Beaches
5 Mixed Sand and Gravel or Shell Beaches
4 Coarse-Grained Sand Beaches
3B Scraps and Steep Slopes in Sand
3A Fine-Grained Sand Beaches
2B Wave-Cut Clay Platforms
2A Scraps and Steep Slopes in Clay
1 Exposed Walls and Other Solid Structures
Oil Spill Planning and Response Atlas
2016
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Depth Soundings in Feet
110

1.b) Peach Point (Justin Hurst) WMA-Bryan Beach and Brazos River; Socio-Economic

Peach Point (Justin Hurst) WMA and Bryan Beach are used primarily for recreational (beach-going, hunting, fishing) purposes. The ICWW runs along the north side of the boundary, and is heavily used for shipping along the Texas coastline.

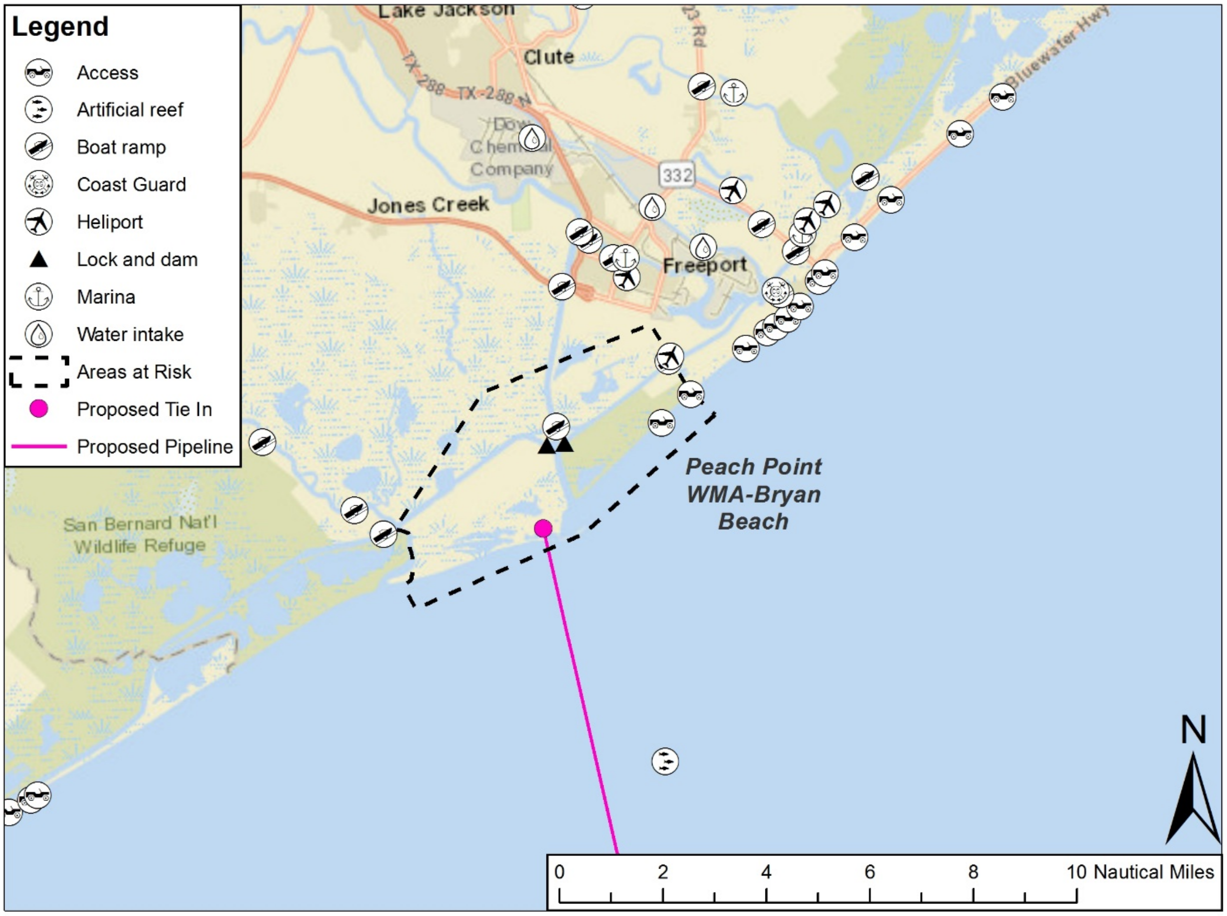


Figure 6 – Socio-Economic Overview of Peach Point (Justin Hurst) WMA-Bryan Beach; Predicted Impact Locations

2.a) San Bernard WMA; Environmental

TGLO Protection Sites: 110-A, 110-B, 110-F, 110-E, 111-D, 111-E, 111-F, 111-G, 111-H, 111-J, 111-K
Threatened or endangered species in this area:

TYPE	SPECIES	STATUS	CONCENTRATION
Bird	Peregrine Falcon	Threatened	N/A
Bird	Piping Plover	Threatened	Individuals
Bird	Reddish Egret	Threatened	Present
Bird	Bald Eagle	Threatened	Nest
Bird	Wood Stork	Threatened	N/A
Bird	White-Faced Ibis	Threatened	Pairs
Marine Mammal	West Indian Manatee	Endangered	Very rare
Reptile	Kemp's Ridley Sea Turtle	Endangered	Common
Reptile	Green Sea Turtle	Threatened	Occasional
Reptile	Hawksbill Sea Turtle	Endangered	Occasional
Reptile	Loggerhead Sea Turtle	Threatened	Occasional

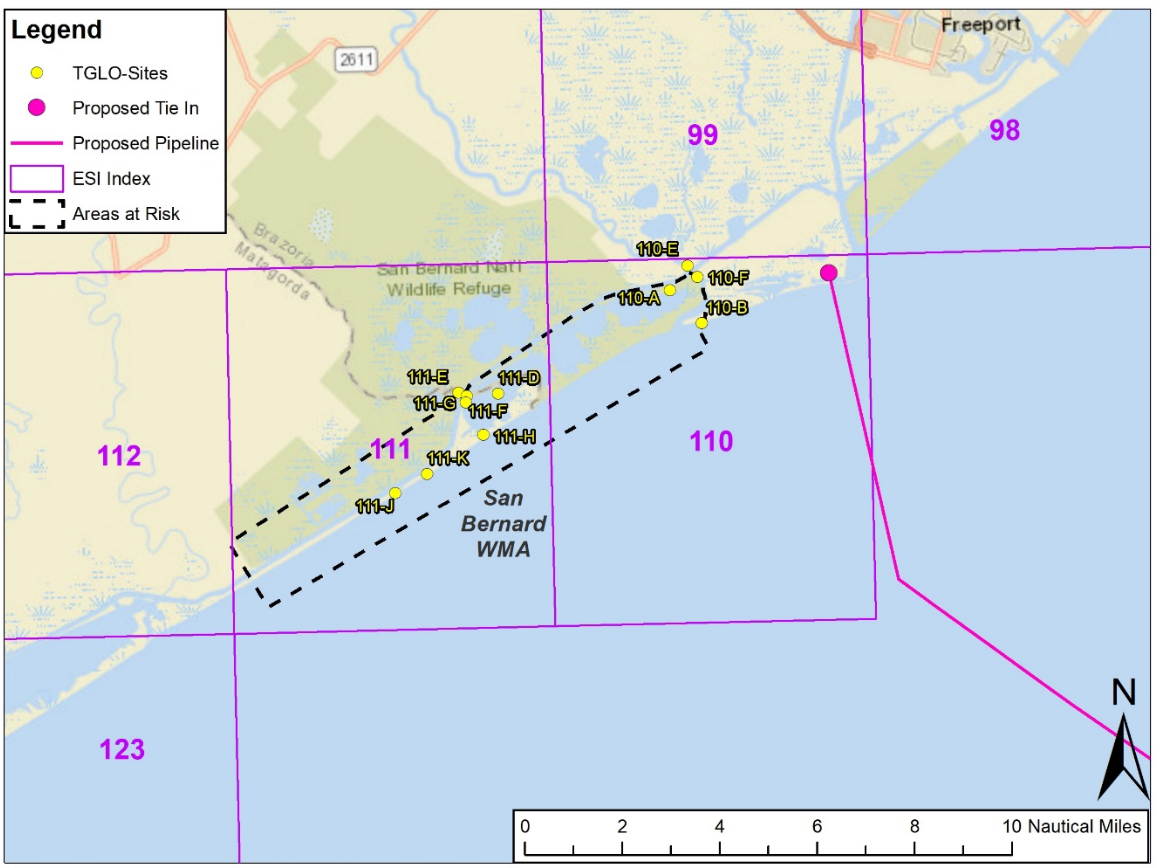
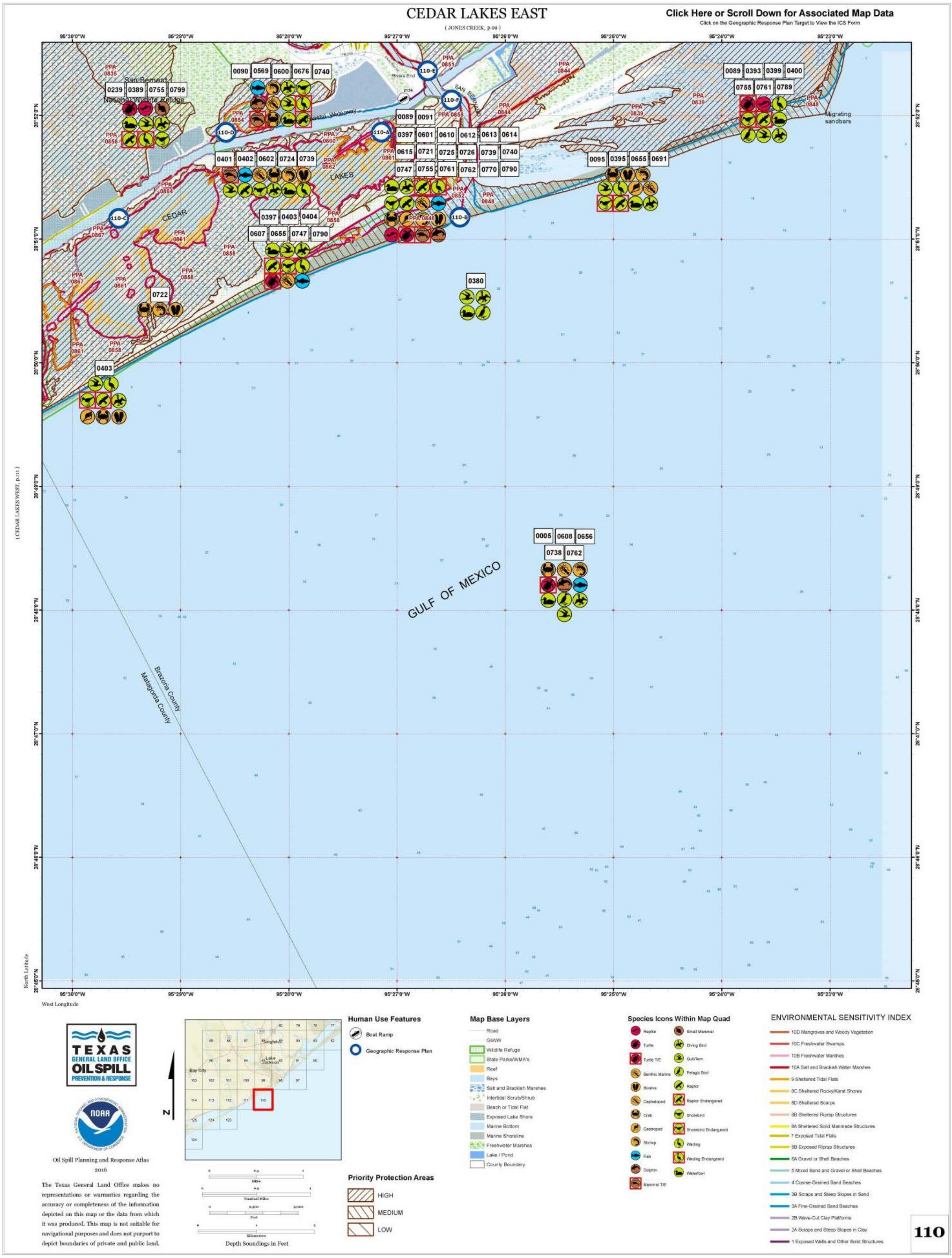


Figure 7 – ESI Index Overview and TGLO Sites of San Bernard WMA; Predicted Impact Locations


CEDAR LAKES EAST
(JONES CREEK, p.99)
Click Here or Scroll Down for Associated Map Data
Click on the Geographic Response Plan Target to View the ICS Form
GULF OF MEXICO
CEDAR LAKES
Migrating sandbars
Brazoria County
Matagorda County
(CEDAR LAKES WEST, p.111)
North Latitude
West Longitude
TEXAS GENERAL LAND OFFICE OIL SPILL PREVENTION & RESPONSE
Oil Spill Planning and Response Atlas
2016
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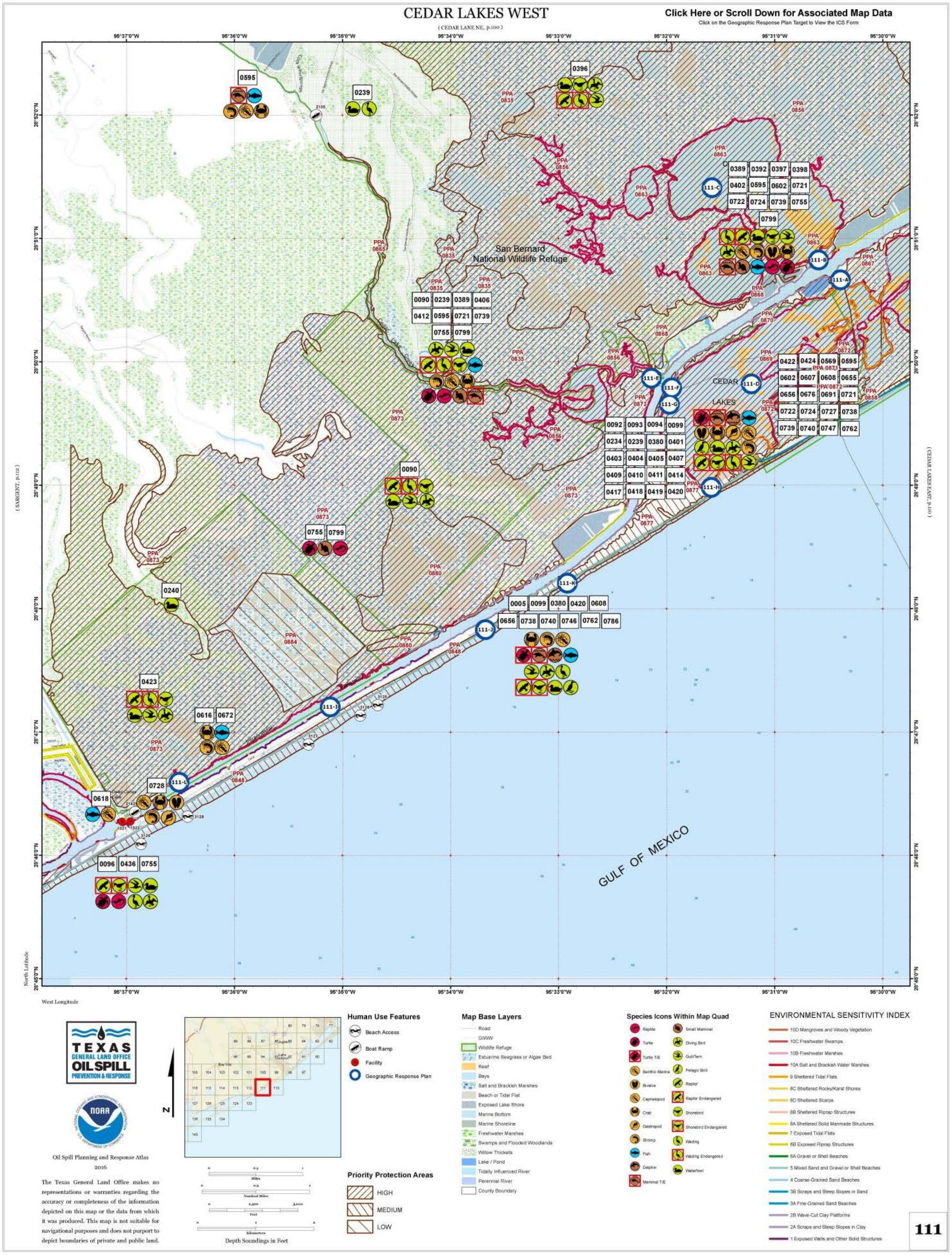
Depth Soundings in Feet
Human Use Features
Boat Ramp
Geographic Response Plan
Priority Protection Areas
HIGH
MEDIUM
LOW
Map Base Layers
Species Icons Within Map Quad
ENVIRONMENTAL SENSITIVITY INDEX
110


CEDAR LAKES WEST
Click Here or Scroll Down for Associated Map Data
San Bernard National Wildlife Refuge
CEDAR LAKES
GULF OF MEXICO
North Latitude
West Longitude
Human Use Features
Beach Access
Boat Ramp
Facility
Geographic Response Plan
Map Base Layers
Road
GIWW
Wildlife Refuge
Estuarine Seagrass or Algae Bed
Reef
Bays
Salt and Brackish Marshes
Beach or Tidal Flat
Exposed Lake Shore
Marine Bottom
Marine Shoreline
Freshwater Marshes
Swamps and Flooded Woodlands
Willow Thickets
Lake / Pond
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Perennial River
County Boundary
Species Icons Within Map Quad
Reptile
Turtle
Turtle T/E
Benthic Marine
Bivalve
Cephalopod
Crab
Gastropod
Shrimp
Fish
Dolphin
Mammal T/E
Small Mammal
Diving Bird
Gull/Tern
Pelagic Bird
Raptor
Raptor Endangered
Shorebird
Shorebird Endangered
Wading
Wading Endangered
Waterfowl
ENVIRONMENTAL SENSITIVITY INDEX
10D Mangroves and Woody Vegetation
10C Freshwater Swamps
10B Freshwater Marshes
10A Salt and Brackish Water Marshes
9 Sheltered Tidal Flats
8C Sheltered Rocky/Karst Shores
8D Sheltered Scarps
8B Sheltered Riprap Structures
8A Sheltered Solid Manmade Structures
7 Exposed Tidal Flats
6B Exposed Riprap Structures
6A Gravel or Shell Beaches
5 Mixed Sand and Gravel or Shell Beaches
4 Coarse-Grained Sand Beaches
3B Scraps and Steep Slopes in Sand
3A Fine-Grained Sand Beaches
2B Wave-Cut Clay Platforms
2A Scraps and Steep Slopes in Clay
1 Exposed Walls and Other Solid Structures
TEXAS GENERAL LAND OFFICE OIL SPILL PREVENTION & RESPONSE
Oil Spill Planning and Response Atlas
2016
The Texas General Land Office makes no representations or warranties regarding the accuracy or completeness of the information depicted on this map or the data from which it was produced. This map is not suitable for navigational purposes and does not purport to depict boundaries of private and public land.
Depth Soundings in Feet
Priority Protection Areas
HIGH
MEDIUM
LOW
111

2.b) San Bernard WMA; Socio-Economic

San Bernard WMA used primarily for recreational purposes. The ICWW runs from East to West, through the middle of the Wildlife Refuge, and is heavily used for shipping along the Texas coastline.

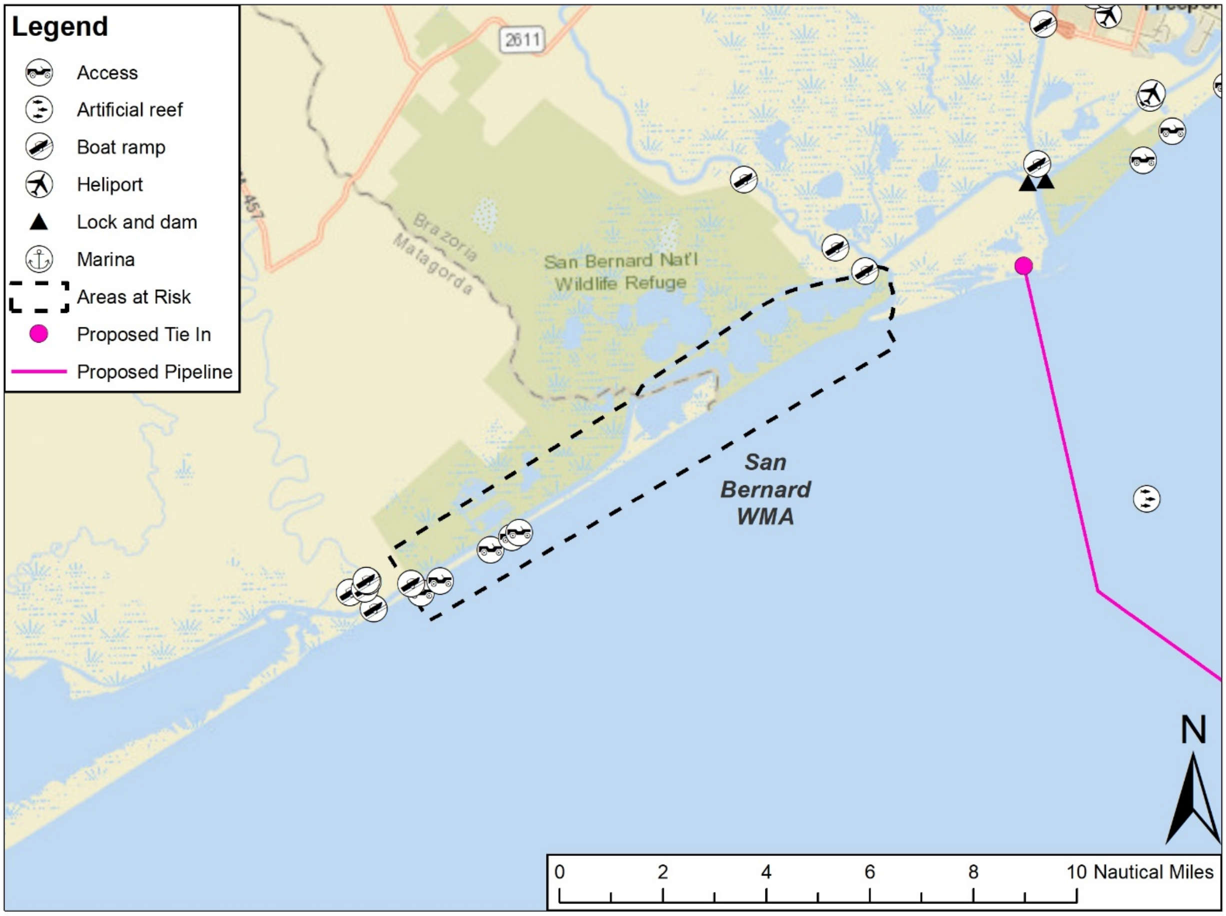

Figure 8 – Socio-Economic Overview of San Bernard WMA; Predicted Impact Locations

ENVIRONMENTAL CONSEQUENCES AND REMEDIATION METHODS

SPILL RESPONSE METHODS FOR SPECIFIC INLAND HABITATS

Oil spill protection, recovery, and cleanup methods are described for four water environments and eight shoreline habitats.

- Description of the environment or habitat;
- Matrices of response methods for four oil types; and
- Short summaries of the key issues considered for each response method.

The habitats are presented in order of their sensitivity, from least to most sensitive to oil spill impact, first for water environments, then for shoreline habitats. Accordingly, water environments begin with large rivers and end with small lakes and ponds. Shoreline habitats begin with bedrock and end with wetlands.

Response methods in each matrix are listed in order, generally beginning with those that cause the least adverse habitat impact, to those that can cause the most adverse habitat impact. Methods for which insufficient information is available for some habitats are listed last.

The use of water environments and shoreline habitats generally reflects the distinction between oil on a water body versus oil that is stranded at the land-water interface. Water-based activities consist mostly of containment, protection, and collection methods while onshore response includes protection, recovery, and cleanup. A large spill will likely affect a wide range of habitats and require use of many different methods. However, large spills can be divided into a series of small spills for developing site-specific response strategies. Often, more than one response method can be used with minimal habitat impacts. Spill conditions may dictate selecting a specific method, or combination of methods, over other possible methods.

SHORELINE TYPES AND CLEANUP METHODS	
1	Open Water
2	Large Rivers
3	Small Lakes and Ponds
4	Small Rivers and Streams
5	Manmade Structures
6	Sand Habitats
7	Mixed Sand and Gravel Habitats
8	Gravel Habitats
9	Vegetated Shoreline Habitats
10	Mud Habitats
11	Wetland Habitat

1. OPEN WATER	
Habitat Description	Open-water environments exist in large water bodies, such as the Great Lakes, Lake Champlain, and Lake Mead. These large water bodies have ocean-like wave and current conditions; however, lake currents are generally weak (less than one knot). Local weather conditions commonly cause sudden changes in sea state. Suspended sediment loads are highly variable, both spatially and over time. River mouths are particularly problematic areas, with high suspended sediment and debris loads, shallow zones, and manmade structures, which create complex water circulation patterns. Thermal stratification with an upper, warm layer over cool, denser water is a common feature of large lakes during the warmer months. In most temperate lakes, stratification ends in the autumn when surface cooling combines with water mixing from high winds. Ice formation is a common characteristic of interior and northern lakes in winter months. Although all inland waters are surrounded by land, response operations for open-water environments are water-based; that is, protection and recovery equipment must be deployed from vessels.
Sensitivity	Open waters are considered to have low to medium sensitivity to oil spill impact because physical removal rates are high, water-column Concentrations of oil can be rapidly diluted, and most organisms are mobile enough to move out of the area affected by the spill. Enclosed and protected areas of large lakes are more sensitive than offshore and nearshore waters because of slower dilution rates. Oil spills can affect fish in the water column, with the early life stages at greatest risk. Also, many birds (waterfowl, raptors, gulls, terns, and diving birds) feed and rest on the water, and therefore are highly vulnerable. Human use of affected areas may be restricted for a period of time, potentially limiting access for navigation, transportation, water intakes, or recreational activities during the spill. Free-floating flora or mats can occur in sheltered bays of nutrient-rich lakes. Such mats may be particularly susceptible to oil because of their location in bays where oil may accumulate. Moreover, the plants are at the water surface (where the oil is) and without underground roots to regenerate after being oiled.

Environmental impact from response methods for OPEN WATER environments.

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions: A = May cause the least adverse habitat impact. B = May cause some adverse habitat impact. C = May cause significant adverse habitat impact. D = May cause the most adverse habitat impact. I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time. "-" = Not applicable for this oil type.

Response Method	*Gasoline Products*	*Diesel Products*	*Medium Oils*	*Heavy Oils*
Booming - Deflection/Exclusion	**A**	**A**	**A**	**A**
Booming - Containment	**-**	**A**	**A**	**A**
Skimming/Vacuum	**-**	**A**	**A**	**A**
In-Situ Burning	**-**	**A**	**A**	**A**
Natural Recovery	**A**	**A**	**B**	**B**
Physical Herding	**B**	**B**	**B**	**B**
Sorbents	**-**	**B**	**B**	**B**
Vegetation Removal	**-**	**B**	**B**	**B**
Emulsion Treating Agents	**-**	**B**	**B**	**B**
Visco-Elastic Agents/Solidifiers	**-**	**B**	**B**	**-**
Dispersants	**D**	**B**	**B**	**-**
Herding Agents	**D**	**B**	**B**	**-**
Manual Oil Removal/Cleaning	**-**	**-**	**-**	**B**
Mechanical Oil Removal	**-**	**-**	**-**	**B**
Nutrient Enrichment	**-**	**-**	**I**	**I**
Natural Microbe Seeding	**-**	**-**	**I**	**I**

RESPONSE METHODS: OPEN WATER ENVIRONMENTS	
Least Adverse Habitat Impact	*Booming* • Most effective in low-wave conditions and slow currents • Safety concerns limit the containment of gasoline spills; however, booms can be used to exclude or deflect the spill away from sensitive resources *Skimming/Vacuum* • Effectiveness limited by current velocities and widely spread, thin sheens • Not applicable to gasoline spills because of safety concerns *In-Situ Burning* • Most appropriate in offshore, rather than nearshore, areas • More difficult to ignite emulsified and heavy oils and sustain the burn • Safety issues for workers, vessels, and aircraft must be addressed • Not applicable to gasoline spills due to safety concerns and containment difficulties *Natural Recovery* • Low impact except for medium- to heavy-category oils, which are persistent and would eventually strand on shorelines
Some Adverse Habitat Impact	*Physical Herding* • May be needed under calm conditions to move oil toward recovery devices • Water spray onto gasoline likely to mix the product into the water column *Sorbents* • Not a stand-alone technique except for very small spills • Inhibit the evaporation of gasoline spills *Vegetation Removal* • May be appropriate if oil is trapped in floating vegetation *Emulsion-Treating Agents* • Not applicable to oils that do not form emulsions, such as gasoline *Visco-Elastic Agents/Solidifiers* • Not appropriate to gasoline spills because of safety concerns during application and inhibition of evaporation • The recovery of treated oil must be considered • Most are not very effective on heavy oils, which are too viscous to allow the product to mix into the oil *Dispersants* • Inhibit the evaporation of gasoline spills • Use requires comparing the impact of dispersed versus undispersed oil • Not effective on heavy or weathered oils *Herding Agents* • Most effective under calm conditions • Not applicable to heavy oils because oil must be fluid • Inhibit the evaporation of gasoline spills *Manual Oil Removal/Cleaning and Mechanical Oil Removal* • Effective only when heavy oils have solidified into large masses • Complete removal of heavy oil is rarely achieved
Insufficient Information	*Nutrient Enrichment and Natural Microbe Seeding* • Not applicable to gasoline and diesel-like oils because they rapidly evaporate • There is insufficient information on impact and effectiveness for other oil types, particularly for open-water applications in freshwater

2. LARGE RIVERS	
Habitat Description	Large rivers have varying salinities, meandering channels, and high flow rates (currents usually greater than one knot). These rivers are not necessarily navigable to large vessels. If they are, the environment can include associated locks, dams, pools, and other manmade structures. Examples of large rivers include the Mississippi River and its major tributaries, the Hudson River, the Delaware River, and the Columbia River. Water levels vary seasonally, with potential for reversal of water flow up tributaries and into backwater lakes during high water. Floodplains are common characteristics of large rivers. Floods generate high suspended sediment and debris loads. In northern regions, ice covers the surface in winter.
Sensitivity	Large rivers have medium sensitivity to oil spill impact because, even though they have high natural removal rates, they also have extensive biological and human use. Biological resources of concern include Concentrations of migratory waterfowl and shorebirds, fish, and endangered mussel beds. Under flood conditions, river floodplains contain highly sensitive areas that are important habitats for many valuable species. Floating vegetation is present in areas of low flow. Recreational use of rivers is very high, and many are major transportation corridors. Drinking, industrial, and cooling water intakes are quite vulnerable to oil spills in this environment because of turbulent mixing, and they often shut down when slicks are present. High currents, eddies, mid-river bars, ice formation, and flooding may complicate response measures in this habitat. Water flow across weirs and dams is of special concern because it is often turbulent and likely to emulsify oil slicks as they pass over these structures. Emulsified oil has a density close to water; it can readily suspend beneath the surface and remain in the water column as it moves through a series of locks and dams. Also, oil can adsorb onto sediment particles, which then settle out in quiet backwaters, potentially contaminating these habitats.

Relative environmental impact from response methods for LARGE RIVER environments.

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions: A = May cause the least adverse habitat impact. B = May cause some adverse habitat impact. C = May cause significant adverse habitat impact. D = May cause the most adverse habitat impact. I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time. "-" = Not applicable for this oil type.

Response Method	*Gasoline Products*	*Diesel Products*	*Medium Oils*	*Heavy Oils*
Booming - Deflection/Exclusion	**A**	**A**	**A**	**A**
Booming - Containment	**-**	**A**	**A**	**A**
Skimming/Vacuum	**-**	**A**	**A**	**A**
Natural Recovery	**A**	**A**	**B**	**C**
Physical Herding	**B**	**B**	**B**	**B**
Sorbents	**-**	**B**	**B**	**B**
In-Situ Burning	**-**	**B**	**B**	**B**
Emulsion Treating Agents	**-**	**B**	**B**	**B**
Vegetation Removal	**-**	**B**	**B**	**B**
Debris Removal	**-**	**B**	**B**	**B**
Visco-Elastic Agents/Solidifiers	**-**	**B**	**B**	**-**
Manual Oil Removal/Cleaning	**-**	**-**	**B**	**B**
Mechanical Oil Removal	**-**	**-**	**B**	**B**
Dispersants	**D**	**C**	**C**	**-**
Herding Agents	**D**	**D**	**D**	**-**
Nutrient Enrichment	**-**	**-**	**I**	**I**

RESPONSE METHODS: LARGE RIVER ENVIRONMENTS	
Least Adverse Habitat Impact	*Booming* • Used primarily for diverting slicks towards collection points in low-current areas • Safety concerns limit the containment of gasoline spills; however, booms can be used to exclude or deflect the spill away from sensitive resources *Skimming/Vacuum* • Not applicable to gasoline spills because of safety concerns
Some Adverse Habitat Impact	*Natural Recovery* • For small gasoline and diesel-like spills, evaporation and natural dispersion would rapidly remove surface slicks • For all other types and sizes of spills, oil recovery and/or protection of sensitive resources should be attempted *Physical Herding* • May be needed to flush oil trapped in debris, eddies, etc. toward recovery devices • Water spray onto gasoline spills will likely enhance mixing of the product into the water column *Sorbents* • Not applicable to gasoline spills because of safety concerns and inhibition of evaporation • May not be practical for large rivers because oil will spread and drift rapidly • Overuse results in excess waste generation *In-Situ Burning* • May not be practical in rivers because oil will spread rapidly • Containment and maintenance of minimum thickness for burning (1-3 millimeters) is difficult in fast currents *Emulsion-Treating Agents* • Not applicable for gasoline products, which do not emulsify *Vegetation Removal* • May be considered where oil is trapped in floating vegetation along shore and in eddies • Removal of oiled vegetation may be required to prevent secondary oiling of wildlife or chronic sheening *Debris Removal* • River debris can trap persistent oils, causing chronic sheening and exposure of aquatic resources *Visco-Elastic Agents/Solidifiers* • Not applicable to gasoline spills because of safety concerns during application and inhibition of evaporation • Recovery of treated oil may be difficult • May not be practical in rivers because oil will spread and drift rapidly • Not effective on heavy oils, which are too viscous to allow the product to mix into the oil *Manual Oil Removal/Cleaning* • Concentrations of heavy oils that have hardened into solid or semi-solid masses can be manually picked up, from boat or shore • Hand tools can be used to pick up small accumulations of oiled debris • Operations conducted from boats minimize potential for habitat disruption by trampling onshore *Mechanical Oil Removal* • May be needed to recover large amounts of oil/oily debris trapped in booms or along shore • Equipment can be operated from barges with less impact; shore-based operations are likely to cause localized disruption of shoreline habitat

RESPONSE METHODS: LARGE RIVER ENVIRONMENTS	
Probable Adverse Habitat Impact	*Dispersants* • Inhibit the evaporation of gasoline spills • Not effective on heavy or weathered oils • For large spills, limited dilution of dispersed oil in rivers likely to raise toxicity concerns • Impacts on water intakes downstream would have to be evaluated
Most Adverse Habitat Impact	*Herding Agents* • High currents make proper application difficult and carry product away • Not applicable to heavy oils because oil must be fluid
Insufficient Information	*Nutrient Enrichment and Natural Microbe Seeding* • Not applicable to gasoline and diesel-like oil spills because they rapidly evaporate • There is insufficient information on impact and effectiveness for other oil types, particularly for applications in rivers

3. SMALL LAKES AND PONDS

Habitat Description	Lakes and ponds are standing bodies of water of variable size and water depth. Waves and currents are generally very low, although the water surface can become choppy. Water levels can fluctuate widely over time, particularly on manmade lakes. Smaller ponds can completely freeze over in winter. The bottom sediments close to shore can be soft and muddy, and the surrounding land can include wet meadows and marshes. Floating vegetation can be common. The rate of water exchange is highly variable within this group, ranging from days to years. These water bodies can include sections of a river with low flow rates (e.g., behind diversion dams) or that are somewhat isolated from regular flow (e.g., backwater lakes or oxbow lakes). Isolated water bodies, such as kettle lakes, are unique members of this category because they have no surface water outflow, and therefore have very low flushing rates. In shallow water, boat operations would be limited and most response operations would be conducted from shore.
Sensitivity	Small lakes and ponds have medium to high sensitivity to oil spill impact because of low physical removal rates, limited dilution and flushing of oil mixed into the water column, and high biological and human use. They provide valuable habitat for migrating and nesting birds and mammals, and support important fisheries. Small lakes can be the focus of local recreational activities. Wind will control the distribution of slicks, holding the oil against a lee shore or spreading it along shore and into catchment areas. Wind shifts can completely change the location of slicks, contaminating previously clean areas. Thus, early protection of sensitive areas is important. The inlet and outlet are key areas for focusing protection efforts. Oil impacts on floating vegetation depend to a large degree on dose, with possible elimination of plants at high doses. Section 5 addresses sinking oils and response under ice conditions.

Environmental impact from response methods for SMALL LAKE & POND environments.

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions: A = May cause the least adverse habitat impact. B = May cause some adverse habitat impact. C = May cause significant adverse habitat impact. D = May cause the most adverse habitat impact. I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time. "-" = Not applicable for this oil type.

Response Method	*Gasoline Products*	*Diesel Products*	*Medium Oils*	*Heavy Oils*
Booming - Deflection/Exclusion	**A**	**A**	**A**	**A**
Booming - Containment	**-**	**A**	**A**	**A**
Skimming/Vacuum	**-**	**A**	**A**	**A**
Sorbents	**-**	**A**	**A**	**A**
Natural Recovery	**A**	**B**	**C**	**C**
In-Situ Burning	**B**	**B**	**B**	**B**
Herding Agents	**B**	**B**	**B**	**-**
Debris Removal	**-**	**B**	**B**	**B**
Vegetation Removal	**-**	**B**	**B**	**B**
Physical Herding	**C**	**B**	**B**	**B**
Visco-Elastic Agents/Solidifiers	**-**	**B**	**B**	**-**
Manual Oil Removal/Cleaning	**-**	**C**	**C**	**B**
Mechanical Oil Removal	**-**	**C**	**C**	**C**
Dispersants	**D**	**D**	**D**	**-**
Emulsion Treating Agents	**-**	**I**	**I**	**I**
Nutrient Enrichment	**-**	**I**	**I**	**I**
Natural Microbe Seeding	**-**	**I**	**I**	**I**

RESPONSE METHODS: SMALL LAKE AND POND ENVIRONMENTS	
Least Adverse Habitat Impact	*Booming* • Use containment booms to keep oil from spreading • Safety concerns limit the containment of gasoline spills; however, booms can be used to exclude or deflect the spill away from sensitive resources *Skimming/Vacuum* • Not applicable to gasoline spills because of safety concerns • Land-based operations need site-specific restrictions and monitoring to minimize physical destruction *Sorbents* • Overuse results in excess waste generation • Inhibit the evaporation of gasoline spills
Some Adverse Habitat Impact	*Natural Recovery* • Low impact for light oils but may have significant impact for medium crudes and heavier fuel oils because they persist and affect shoreline habitats *In-Situ Burning* • Less environmental impact in winter when snow and ice provide some protection, plants are dormant, and fewer animals are present • Safety concerns limit containment of gasoline, but may be safely used with natural containment, such as gasoline trapped in ice *Herding Agents* • Most effective under calm conditions • Should be coupled with recovery when used to protect sensitive habitats • Not effective on heavy oils because oil must be fluid *Debris Removal* • Debris may be associated with nests or living areas (e.g., beaver lodges), so impacts on resident animal habitat may need consideration • Operate from small boats to minimize substrate disruption *Vegetation Removal* • If oil is trapped in floating vegetation, may be only way to recover the oil in the absence of water currents • May be appropriate to prevent secondary oiling of wildlife *Physical Herding* • Care should be taken not to drive oil into the water column or sediment *Visco-Elastic Agents/Solidifiers* • Visco-elastic agents, by improving overall oil recovery from the water surface, reduce secondary shoreline oiling • Not applicable to gasoline spills because of safety concerns during application and inhibition of evaporation • Not effective on heavy oils, which are too viscous to allow the product to mix into the oil
Probable Adverse Habitat Impact	*Manual Oil Removal/Cleaning* • Inherent inefficiency of manual removal of fluid oils would require large crews or repeated entries, resulting in disruption to substrate and wildlife • Not applicable for gasoline spills because of safety concerns *Mechanical Oil Removal* • May be needed where oil has heavily contaminated bottom sediments • May require very intrusive recovery techniques
Most Adverse Habitat Impact	*Dispersants* • Inhibit the evaporation of gasoline spills • Shallow water depths and low dilution rates may result in high aquatic toxicity from oil/dispersant mixtures

RESPONSE METHODS: SMALL LAKE AND POND ENVIRONMENTS	
Insufficient Information	*Emulsion-Treating Agents* • Not applicable to oils that do not form emulsions, such as gasoline • Insufficient toxicity data to evaluate environmental impact of shallow freshwater environment use *Nutrient Enrichment and Natural Microbe Seeding* • Not applicable to gasoline spills because they rapidly evaporate • There is insufficient information on impact and effectiveness for other oil types • There are special concerns about nutrient overloading in small, restricted water bodies

4. SMALL RIVERS AND STREAMS

Habitat Description	Small rivers and streams are characterized by shallow water (generally 1-2 meters) and narrow channels. Water flow can be highly variable, both throughout the seasons and with distance downstream. This grouping includes a wide range of waterbodies, from fast-flowing streams with low falls and numerous rapids over bedrock and gravel, to slow-moving bayous bordered by low muddy banks and fringed with vegetation. Sections of the channel may be choked with log jams and debris, and mid-channel bars and islands can divide water flow into multiple channels. Both boat and vehicular access can be very limited; often the only access will be at bridge crossings. Ice may further complicate response measures in this habitat.
Sensitivity	Small rivers and streams have medium to high sensitivity to oil spill impact. Oil spills may have more of an impact on small rivers and streams than on large rivers due to a variety of conditions, such as lower flow conditions, lower dilution rates, lower overall energy, and greater range of natural habitats. Fish spawn in streams and the tributaries of larger rivers; thus, the most sensitive, early life stages can be present. Fringing wetlands and adjacent floodplains are closely connected to small rivers and streams, and they are areas of high biological use and low natural removal rates. Slicks usually contaminate both banks, and non-viscous oils are readily mixed into the entire water column in shallow streams, potentially exposing both aquatic and benthic organisms to oil. Initial weathering rates may be slower because spreading and evaporation are restricted in narrow channels and heavy vegetation cover. Fish kills are possible for spills ranging from gasoline to medium crude oils. Many different kinds of mammals, birds, reptiles, and amphibians use the stream bank habitats, and there can be localized high mortality rates of these animals. Spills can cause closure of water intakes for drinking water, irrigation, or industrial use along small rivers. A more aggressive response may be appropriate to prevent contamination of downstream habitat, particularly if water intakes, populated areas, or special habitat resources are present.

Environmental impact from response methods for SMALL RIVER & STREAM environments.

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions: A = May cause the least adverse habitat impact. B = May cause some adverse habitat impact. C = May cause significant adverse habitat impact. D = May cause the most adverse habitat impact. I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time. "-" = Not applicable for this oil type.

Response Method	*Gasoline Products*	*Diesel Products*	*Medium Oils*	*Heavy Oils*
Booming - Deflection/Exclusion	**A**	**A**	**A**	**A**
Skimming	**A**	**A**	**A**	**A**
Booming - Containment	**-**	**A**	**A**	**A**
Vacuum	**-**	**A**	**A**	**A**
Sorbents	**-**	**A**	**A**	**A**
Barriers/Berms	**B**	**A**	**A**	**A**
Physical Herding	**B**	**B**	**B**	**B**
Natural Recovery	**A**	**B**	**C**	**C**
Debris Removal	**-**	**B**	**B**	**B**
Visco-Elastic Agents/Solidifiers	**B**	**B**	**B**	**-**
Vegetation Removal	**-**	**B**	**B**	**B**
In-Situ Burning	**C**	**B**	**B**	**B**
Manual Oil Removal/Cleaning	**-**	**C**	**C**	**B**
Mechanical Oil Removal	**-**	**C**	**C**	**C**
Dispersants	**D**	**D**	**D**	**-**
Herding Agents	**D**	**D**	**D**	**-**
Emulsion Treating Agents	**-**	**I**	**I**	**I**
Nutrient Enrichment	**-**	**I**	**I**	**I**
Natural Microbe Seeding	**-**	**I**	**I**	**I**

RESPONSE METHODS: SMALL RIVER AND STREAM ENVIRONMENTS	
Least Adverse Habitat Impact	*Booming* • Used primarily to divert slicks towards collection points in low-current areas • Safety concerns limit the containment of gasoline spills; however, booms can exclude or deflect the spill away from sensitive resources • Expect low effectiveness with fast currents, shallow water, and steep banks *Skimming/Vacuum* • To protect public health and downstream resources where spreading is limited, recovery of large gasoline spills could be attempted with firefighting foam to suppress vapors and respiratory protection for workers *Sorbents* • Deploy in booms to recover sheens in low-current areas and along shore • Trampling of stream bank and bed habitats during deployment and recovery of sorbents can disrupt streamside vegetation and drive oil into the sediment • Overuse results in excess waste generation *Barriers/Berms* • Potential for physical disruption and sediment contamination in immediate area of the barrier/berm • If all or most of the flow is diverted, may need to monitor water requirements to habitats downstream of the barrier to mitigate potential impacts • Safety concerns limit actions at gasoline spills, although berms built ahead of the slick could be used to exclude oil from sensitive areas, such as side channels
Some Adverse Habitat Impact	*Physical Herding* • May be only means to flush oil trapped in log jams, beaver dams, behind rocks, and in vegetation/debris along banks to downstream collection areas • Spraying of gasoline spills can mix the oil into the water column *Natural Recovery* • For small gasoline and diesel-like oil spills, evaporation and natural dispersion would rapidly remove surface slicks • For all other types and sizes of spills, recovery of free or pooled oil and/or protection of sensitive resources should be attempted *Debris Removal* • Will release trapped oil and speed natural flushing rates*Visco-Elastic Agents/Solidifiers* • Visco-elastic agents may speed recovery of contained oil when time is critical • Solidifiers may immobilize even gasoline spills, preventing their transport downstream and further impact • Ineffective on heavy oils, which are too viscous to allow the product to mix into the oil *Vegetation Removal* • May be needed to remove oil trapped in floating and fringing vegetation • Remove oiled vegetation to prevent chronic sheening in sensitive areas or secondary oiling of wildlife • Monitor crews to minimize physical disturbance, which can be severe *In-Situ Burning* • May be difficult to protect stream-side vegetation • Safety concerns limit containment of gasoline, but may be safely used if natural containment is present • Less impact in winter when snow/ice provide some protection, plants are dormant, and fewer animals are present • May not be practical in fast flowing streams where containment and maintenance of minimum slick thickness (1-3 millimeters) may be difficult
Probable Adverse Habitat Impact	*Manual Oil Removal/Cleaning* • Viable for heavy oils that have solidified versus fluid oils that have spread • Stream bank disruption likely from movement of work crews *Mechanical Oil Removal* • Only consider when large amounts of solidified oil have accumulated in the stream channel and need to be removed quickly

RESPONSE METHODS: SMALL RIVER AND STREAM ENVIRONMENTS	
Most Adverse Habitat Impact	*Dispersants* • Enhanced mixing of oil into the water column with restricted dilution will increase acute toxicity to aquatic organisms *Herding Agents* • Toxicity concerns when early life stages are present • May not be practical due to fast currents and rough water surface • Oil must be fluid, so not appropriate to heavy oils
Insufficient Information	*Emulsion-Treating Agents* • Insufficient toxicity data to evaluate environmental impact of shallow freshwater environment use • Not applicable to oils that do not form emulsions, such as gasoline *Nutrient Enrichment and Natural Microbe Seeding* • Not applicable to gasoline spills because they rapidly evaporate • There is insufficient information on impact and effectiveness, particularly for applications in small rivers and streams

5. MANMADE STRUCTURES (ESI = 1B, 6B, 8B)	
Habitat Description	Manmade structures include vertical shore protection structures such as seawalls, piers, and bulkheads, as well as riprap revetments and groins, breakwaters, and jetties. Vertical structures can be constructed of concrete, wood, and corrugated metal. They usually extend below the water surface, although seawalls can have beaches or riprap in front of them. Riprap revetments are constructed of boulder-sized pieces of rock, rubble, or formed concrete pieces (e.g., tetrapods), placed parallel to the shoreline for shore protection. Riprap groins are oriented perpendicular to shore to trap sediment; jetties are designed to protect and maintain channels; and breakwaters are offshore structures constructed to protect an area from wave attack. Riprap structures have very large void spaces and are permeable, while seawalls and bulkheads have impermeable, solid substrates. These structures are very common along developed shores, particularly in harbors, marinas, and residential areas. The range in degree of exposure to waves and currents varies widely, from very low in dead-end canals, to very high on offshore breakwaters. Boat wakes can generate wave energy in otherwise sheltered areas.
Sensitivity	Manmade structures have a range of sensitivities to oil spills, depending on the degree of exposure to natural removal processes. Biological communities and use are sparse. Often, there are sources of pollutants or habitat degradation nearby, such as urban runoff, chronic small oil spills in marinas, poor water quality, and limited water circulation. More intrusive cleanup techniques are often conducted due to their lower biological use, higher public demand for oil removal for aesthetic reasons, and need to minimize human exposure to oil in populated areas. It is acknowledged that manmade structures can vary in permeability, cohesion, and mobility and, in turn, how they are affected by oiling. In this document, however, manmade structures have been grouped together so that the higher degree of cleanup often required can be adequately addressed. Vertical structures are generally impermeable to oil penetration, but oil can heavily coat rough surfaces, forming a band at the water line. During storms, oil can splash over the top and contaminate terrestrial habitats. Riprap poses significant cleanup problems because of large void spaces between the riprap and heavy accumulations of debris. Large amounts of oil can become trapped in the riprap, where it is difficult to remove and a potential source of sheening.

Environmental impact from response methods for MANMADE structures (ESI = 1B, 6B, 8B).

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions: A = May cause the least adverse habitat impact. B = May cause some adverse habitat impact. C = May cause significant adverse habitat impact. D = May cause the most adverse habitat impact. I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time. "-" = Not applicable for this oil type.

Response Method	*Gasoline Products*	*Diesel Products*	*Medium Oils*	*Heavy Oils*
Manual Oil Removal/Cleaning	**-**	**A**	**A**	**A**
Debris Removal	**-**	**A**	**A**	**A**
High-Pressure, Cold-Water Flushing	**B**	**A**	**A**	**B**
Sorbents	**B**	**A**	**A**	**B**
Vacuum	**-**	**B**	**A**	**A**
Natural Recovery	**A**	**A**	**B**	**B**
Flooding	**B**	**A**	**A**	**C**
Low-Pressure, Cold-Water Flushing	**B**	**A**	**A**	**C**
Low-Pressure, Hot-Water Flushing	**-**	**B**	**B**	**B**
High-Pressure, Hot-Water Flushing	**-**	**B**	**B**	**B**
Shoreline Cleaning Agents	**-**	**B**	**B**	**B**
Solidifiers	**B**	**B**	**B**	**-**
In-Situ Burning	**-**	**B**	**B**	**B**
Nutrient Enrichment	**-**	**C**	**C**	**D**
Steam Cleaning	**-**	**C**	**C**	**C**
Chemical Shoreline Pretreatment	**-**	**I**	**I**	**I**

RESPONSE METHODS: MANMADE STRUCTURES	
Least Adverse Habitat Impact	*Manual Oil Removal/Cleaning and Debris Removal* • Effective for removing debris and small, persistent pockets of oil *High-Pressure, Cold-Water Flushing* • Effective for removing sticky oils from solid surfaces and flushing pooled oil from riprap crevices, even for gasoline in populated areas • May flush oiled sediments (if present) into nearshore bottom habitats • Use on heavy oils is likely to leave large amounts of residual oil in the environment • Use on gasoline spills may transport the oil to more sensitive habitats *Sorbents* • Use along riprap structures to recover residual sheening oil after other cleanup methods have been conducted, even for gasoline • Physical removal rates of heavy oils will be slow, so less oil will be mobilized for recovery by sorbents • Overuse results in excess waste generation *Vacuum* • Early use of vacuum on pooled oil in crevices can increase the oil recovery rate and minimize oil losses during flushing • Can only remove thick oil from accessible areas, so high residual oil likely *Natural Recovery* • Most effective for lighter oils and more exposed settings • Heavier oils may necessitate removing persistent residues
Some Adverse Habitat Impact	*Flooding* • Not applicable to seawalls; on riprap, only effective when the oil is fluid • May be used on riprap in developed areas, even for gasoline spills, where pockets of the spilled product pose human health concerns • Use on heavy oils is likely to leave large amounts of residual oil in the environment • Use on gasoline spills may transport the oil to more sensitive habitats *Low-Pressure, Cold-Water Flushing* • Only effective when the oil is fluid • Directed water spray can help remove trapped oil, even for gasoline • Use on heavy oils is likely to leave large amounts of residual oil in the environment • Use on gasoline spills may transport the oil to more sensitive habitats *Low-Pressure, Hot-Water Flushing and High-Pressure, Hot-Water Flushing* • Assumes that there are no biological communities in or immediately downslope from treatment area • High water temperatures are often needed to liquefy heavy oils • High water pressures are often needed to remove weathered oils from solid substrates and riprap *Shoreline Cleaning Agents* • Individual products vary in their toxicity and ability to recover the treated oil *Solidifiers* • Appropriate to recover and control chronic sheening, even for gasoline • Not effective on heavy oils, which are too viscous to allow the product to mix into the oil *In-Situ Burning* • Thick oil likely to occur as isolated pockets that are difficult to access and burn • There will be concerns about air pollution and physical nature of the residue • Public safety issues for burning in developed areas will be of special concern
Probable Adverse Habitat Impact	*Nutrient Enrichment* • Not applicable to gasoline spills because they rapidly evaporate • Concerns about nutrient overloading in poorly flushed areas or where nutrient toxicity, especially ammonia, might be significant • Potentially effective for lighter oils that leave thin residues; less effective for thick, weathered oil residues *Steam Cleaning and Sand Blasting* • Used when removing persistent oil is required for aesthetic reasons

RESPONSE METHODS: MANMADE STRUCTURES	
Insufficient Information	*Chemical Shoreline Pretreatment* • There is insufficient information on available products, their effectiveness, and impact *Natural Microbe Seeding* • There is insufficient information on impact and effectiveness, particularly for applications on manmade structures

6. SAND HABITATS (ESI = 4)	
Habitat Description	Sand habitats have a substrate composed of sediments that are predominantly finer than 2 millimeters but greater than silt or clay-sized material. The shoreline may consist of well-sorted sands of one principal size, or of poorly sorted mixtures of muddy sand, gravelly sand, or a combination of these two. When the sediments are fine-grained sand, beaches may be wide and flat; where the sediments are coarse-grained sand, they usually are steeper and narrower. Sandy shorelines may be naturally eroding, accreting, or stable, and groins or breakwaters may be placed to trap sand and maintain some beaches. Exposed sand beaches can undergo rapid erosional or depositional changes during storms. In developed areas, sand beaches can be artificially created by man and are commonly used for recreation. Sand bars and banks along rivers are also included in this habitat.
Sensitivity	Sand habitats have low to medium sensitivity to oil spills. They generally do not have sizable biological communities except where the habitat tends to be protected and consists of poorly sorted muddy sediments. Thus, ecological effects are likely to be of limited extent because of the low natural biological productivity. In developed areas, sand beaches are considered sensitive because of their high recreational use. During small spills, oil will concentrate in a band along the swash line. Maximum penetration into fine-grained sand will be less than 15 centimeters; penetration in coarse sand can reach 25 centimeters or greater. Clean sand can bury oiled layers quickly, creating more difficult cleanup issues. On heavily used recreational beaches, extensive cleanup is usually required to remove as much of the oil as possible. When large amounts of sediment must be removed, it may be necessary to replace these sediments with clean material. Traffic on sand can push oil deeper.

Environmental impact from response methods for SAND habitats (ESI = 4).				
The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions: A = May cause the least adverse habitat impact. B = May cause some adverse habitat impact. C = May cause significant adverse habitat impact. D = May cause the most adverse habitat impact. I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time. "-" = Not applicable for this oil type.				
Response Method	*Gasoline Products*	*Diesel Products*	*Medium Oils*	*Heavy Oils*
Debris Removal	**-**	**A**	**A**	**A**
Natural Recovery	**A**	**A**	**B**	**B**
Flooding	**B**	**A**	**A**	**B**
Sorbents	**-**	**A**	**A**	**B**
Manual Oil Removal/Cleaning	**D**	**B**	**A**	**A**
Mechanical Oil Removal	**D**	**B**	**B**	**A**
Low-Pressure, Cold-Water Flushing	**B**	**B**	**B**	**B**
Vacuum	**-**	**B**	**B**	**B**
Sediment Reworking	**D**	**B**	**B**	**B**
Nutrient Enrichment	**-**	**B**	**B**	**C**
Shoreline Cleaning Agents	**-**	**-**	**B**	**B**
Solidifiers	**-**	**B**	**B**	**-**
In-Situ Burning	**-**	**-**	**B**	**B**
Low-Pressure, Hot-Water Flushing	**D**	**C**	**C**	**B**
High-Pressure, Cold-Water Flushing	**D**	**D**	**D**	**D**
High-Pressure, Hot-Water Flushing	**D**	**D**	**D**	**D**
Chemical Shoreline Pretreatment	**-**	**I**	**I**	**I**
Natural Microbe Seeding	**-**	**I**	**I**	**I**

<table>
<tr><th colspan="2">RESPONSE METHODS: SAND HABITATS</th></tr>
<tr><td>Least Adverse Habitat Impact</td><td>Debris Removal
• Degree of oiling that warrants debris removal and disposal depends on use by humans and sensitive resources
Natural Recovery
• Lower impact for small spills, lighter oil types, and remote areas
Flooding
• Only effective when the oil is fluid and on the sand surface, rather than penetrated or buried
• Use on heavy oils is likely to leave large amounts of residual oil in the environment
• Use on gasoline spills may transport the oil to more sensitive habitats
Sorbents
• Not applicable to gasoline spills because they rapidly evaporate
• Physical removal rates of heavy oils will be slow, so less oil will be mobilized for recovery by sorbents
• Overuse results in excess waste generation</td></tr>
<tr><td>Some Adverse Habitat Impact</td><td>Manual Oil Removal/Cleaning
• Minimizes sediment removal and problems of erosion and waste disposal
• Effective when oil is mostly on the surface, not buried beneath clean sand
• Gasoline tends to quickly evaporate; therefore habitat disruption, worker safety concerns, and waste generated by manual cleanup are not balanced by benefits in removing oil
Mechanical Oil Removal
• Tends to remove large amounts of clean sand with the oiled sand
• Use on high-use beaches where rapid removal of oil is required and where long stretches of shoreline are heavily oiled
• Gasoline tends to quickly evaporate; therefore habitat disruption, worker safety concerns, and waste generated from mechanical cleanup are not balanced by benefits in removing oil
Low-Pressure, Cold-Water Flushing
• Only effective when the oil is fluid and adheres loosely to the sediments
• Optimize pressure to minimize the amount of sand washed downslope
Vacuum
• Early use of vacuum on pooled, liquid oil can prevent deeper penetration
• Will minimize amount of sorbent waste when used with flushing efforts
• Can vacuum heavy, non-sticky oil from sand substrates completely, but slowly
Sediment Reworking
• Appropriate for lightly oiled and stained sediments, to speed removal rates, and as a final step to polish recreational beaches
• Because gasoline tends to quickly evaporate, habitat disruption, worker safety concerns, and waste generated from sediment reworking are not balanced by benefits in removing oil
Nutrient Enrichment
• Potentially effective for lighter oils that leave thin residues; less effective for thick, weathered oil residues
• May be concern about nutrient overloading in poorly flushed areas
• Not applicable to gasoline spills because they rapidly evaporate
Shoreline Cleaning Agents
• May be only technique to remove viscous oils without removing sediment
• Individual products vary in their toxicity and ability to recover the treated oil
Solidifiers
• Not applicable to gasoline spills because they rapidly evaporate
• Early use may prevent pooled oil from penetrating deeper
• Not effective on heavy oils, which are too viscous to allow the product to mix into the oil
In-Situ Burning
• Can effectively remove pooled surface oil accumulations
• Concerns about air pollution, physical nature of the residue, and thermal impact on biota
• May have to dig trenches to accumulate oil in pools
• Lighter oils will penetrate the sand, leaving insufficient surface Concentrations to burn</td></tr>
</table>

RESPONSE METHODS: SAND HABITATS	
Probable Adverse Habitat Impact	*Low-Pressure, Hot-Water Flushing* • May be needed to soften and lift sticky oil off the sand surface • Any organisms present will be adversely affected by hot water
Most Adverse Habitat Impact	*High-Pressure, Cold-Water Flushing And High-Pressure, Hot-Water Flushing* • High-pressure water jets will fluidize sand-sized sediments, erode the beach, and wash the oiled sediment into nearshore habitats
Insufficient Information	*Chemical Shoreline Pretreatment* • More information needed on available products, their effectiveness, and impact *Natural Microbe Seeding* • There is insufficient information on impact and effectiveness in freshwater habitats

7. MIXED SAND AND GRAVEL HABITATS (ESI = 3, 5)

Habitat Description	Mixed sand and gravel habitats are characterized by a substrate that is composed predominantly of a mixture of sand- to cobble-sized sediments. These habitats may vary from a well-sorted cobble layer overlying finer-grained (sand-sized) sediments to mixtures of sand, pebble, and cobble. Typically, well-sorted beaches are exposed to some wave or current action that separates and transports finer-grained sediments; however, the sediment distribution does not necessarily indicate the energy at a particular shoreline. On depositional beaches multiple berms can be formed at the different water levels generated during storms. In glaciated areas, the gravel component can include very large boulders. Natural replenishment rates are very slow for gravel, compared to sand. Mixed sand and gravel habitats occur as beaches along the Great Lakes and as point bars along rivers and streams.
Sensitivity	Mixed sand and gravel habitats have medium sensitivity to oil spills. Biological communities are very sparse because of sediment mobility, desiccation, and low organic matter. Most invertebrates living in this habitat are deep burrowers, such as some oligochaete worms and insect larvae. Characteristic insects are mayflies, stoneflies, caddisflies, and midges, although mayflies and stoneflies are scarce or absent where silt is present. The nearshore habitat is used by fish for spawning and protects fry and larvae. There are also limited numbers of birds and mammals. Viscous oils reaching these habitats may not penetrate into the sediments because the pore spaces between sediments are filled with sand. Therefore, deep oil penetration and long-term persistence are lower than on gravel substrates. However, oil can still occur at depths below those of annual reworking, particularly if the oil is deposited high on the beach out of the reach of normal wave activity or is rapidly buried. Erosion can be a concern when large quantities of sediment are physically removed. In more sheltered areas, asphalt pavements can form if heavy surface oil deposits are not removed. Once formed, these pavements are very stable and can persist for years.

Environmental impact from response methods for MIXED SAND and GRAVEL habitats (ESI = 3, 5).

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions: A = May cause the least adverse habitat impact. B = May cause some adverse habitat impact. C = May cause significant adverse habitat impact. D = May cause the most adverse habitat impact. I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time. "-" = Not applicable for this oil type.

Response Method	*Gasoline Products*	*Diesel Products*	*Medium Oils*	*Heavy Oils*
Debris Removal	-	A	A	A
Flooding	A	A	A	C
Natural Recovery	A	A	B	B
Low-Pressure, Cold-Water Flushing	B	A	A	B
Sorbents	-	A	A	B
Vacuum	-	B	B	B
Manual Oil Removal/Cleaning	D	B	A	A
Sediment Reworking	D	B	B	B
Mechanical Oil Removal	D	C	B	B
Shoreline Cleaning Agents	-	-	B	B
Nutrient Enrichment	-	B	B	C
In-Situ Burning	-	-	B	B
Solidifiers	-	-	B	-
High-Pressure, Cold-Water Flushing	C	C	C	C
Low-Pressure, Hot-Water Flushing	D	C	C	B
High-Pressure, Hot-Water Flushing	D	D	D	D
Steam Cleaning	-	D	D	D
Chemical Shoreline Pretreatment	-	I	I	I
Natural Microbe Seeding	-	I	I	I

RESPONSE METHODS: MIXED SAND AND GRAVEL HABITATS	
Least Adverse Habitat Impact	*Debris Removal* • Degree of oiling that warrants debris removal and disposal depends on amount of use by humans and sensitive resources *Flooding* • Most effective when the oil is fluid and adheres loosely to the sediments • Use on heavy oils is likely to leave large amounts of residual oil in the environment *Natural Recovery* • Least impact for small spills, lighter oil types, and remote areas *Low-Pressure, Cold-Water Flushing* • Most effective when the oil is fluid and adheres loosely to the sediments • Excessive pressures can cause erosion • Use on heavy oils is likely to leave large amounts of residual oil in the environment • Use on gasoline spills may transport the oil to more sensitive habitats *Sorbents* • Overuse generates excess waste • Useful for recovering sheens, even for gasoline spills • Physical removal rates of heavy oils will be slow, so less oil will be mobilized for recovery by sorbents
Some Adverse Habitat Impact	*Vacuum* • Early use of vacuum on pooled, liquid oil can prevent deeper penetration *Manual Oil Removal/Cleaning* • Gasoline tends to evaporate quickly; therefore manual cleanup causes habitat disruption, worker safety concerns, and generates waste with no benefits due to removing oil • Minimizes sediment removal and problems of erosion and waste disposal • Preferable when oil is mostly on the surface, not deeply penetrated or buried *Sediment Reworking* • Use to break up heavy surface oil or expose persistent subsurface oil deposits, particularly where sediment removal will cause erosion • Use where there is sufficient exposure to waves to rework the sediments into their original profile and distribution • Gasoline tends to evaporate quickly; therefore sediment reworking causes habitat disruption, worker safety concerns, and generates waste with no benefits due to removing oil *Mechanical Oil Removal* • Tends to remove large amounts of sediment with the oil • Applicable for heavier oil types, which are difficult to remove otherwise • Gasoline tends to evaporate quickly; therefore mechanical cleanup causes habitat disruption, worker safety concerns, and generates waste with no benefits from removing oil *Shoreline Cleaning Agents* • May be only technique to remove viscous oils without removing sediment • Individual products vary in their toxicity and ability to recover the treated oil *Nutrient Enrichment* • Not applicable to gasoline spills because they rapidly evaporate • Potentially effective for lighter oils that leave thin residues; less effective for thick, weathered oil residues • Most applicable as a secondary technique after gross oil removal • Concerns about nutrient overloading in poorly flushed areas *In-Situ Burning* • Can effectively remove pooled surface oil accumulations • Concerns about air pollution, physical nature of the residue, and thermal impact on biota • May have to dig trenches to accumulate oil in pools • Lighter oils will not remain on the sediment surface *Solidifiers* • Early use may prevent pooled oil from penetrating deeper • Not applicable to gasoline spills because they rapidly evaporate • May be useful in recovering sheens when deployed as booms and pillows • Not effective on heavy oils, which are too viscous to allow the product to mix into the oil • Could use for lighter oils with correct product and situation

RESPONSE METHODS: MIXED SAND AND GRAVEL HABITATS	
Probable Adverse Habitat Impact	*High-Pressure, Cold-Water Flushing* • High-pressure water jets will flush oiled sediments into nearshore habitats • Excessive pressures can cause erosion if large amounts of sand are present *Low-Pressure, Hot-Water Flushing* • Any organisms present will be affected by hot water • Use on gasoline spills may transport the oil to more sensitive habitats
Most Adverse Habitat Impact	*High-Pressure, Hot-Water Flushing* • Will flush oiled sand into nearshore zone and affect any organisms present *Steam Cleaning* • Highly intrusive technique; will kill any organisms present • Potential for released oil to penetrate deeper into the sediments
Insufficient Information	*Chemical Shoreline Pretreatment* • Need more information on available products, their effectiveness, and impact *Natural Microbe Seeding* • There is insufficient information on impact and effectiveness in freshwater habitats

8. GRAVEL HABITATS (ESI = 6A)

Habitat Description	Gravel habitats are characterized by a substrate that is composed predominantly of gravel-sized sediments. By definition, gravel includes sediments ranging in size from granules (greater than 2 millimeters) to boulders (greater than 256 millimeters). The sand fraction on the surface is usually less than ten percent, although the sand content can increase to 20 percent with depth. These sediments are highly permeable because there are few sand-sized sediments to fill the pore spaces between the individual gravel particles. Gravel substrates may also have low bearing capacity and, consequently, may not support vehicular traffic. Typically, well-sorted beaches are exposed to some wave or current action that reworks the sediments and removes the finer-grained sediments. However, the sediment distribution does not necessarily indicate the energy setting at a particular shoreline; sheltered beaches can still have a large gravel source. In glaciated areas, the gravel can include very large boulders. On depositional beaches, zones of pure pebbles or cobbles can form into multiple berms at the different water levels generated during storms. Gravel shorelines tend to be steeper than those composed of sand or mud. Natural replenishment rates are very slow for gravel compared to sand. Gravel habitats occur as beaches along the Great Lakes and as bars along rivers and streams.
Sensitivity	Gravel habitats have medium sensitivity to oil spills. Biological communities are very sparse because of sediment mobility, desiccation, and low organic matter. Characteristic insects are mayflies, stoneflies, caddisflies, and midges, all with larvae living among the sediments. Flatworms, leeches, and crustaceans may be found on the gravel undersides. The nearshore habitat is used by fish for spawning and provides protection for fry and larvae. Gravel habitats are ranked higher in sensitivity than sand and gravel habitats because deep penetration of stranded oil into the permeable substrate is likely. Oil can penetrate to depths below those of annual reworking, resulting in long-term persistence of the oil. The slow replenishment rate makes removing oiled gravel highly undesirable. Also, formation of persistent asphalt pavements is likely where there is high accumulation of persistent oils.

Environmental impact from response methods for GRAVEL habitats (ESI = 6A).

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions: A = May cause the least adverse habitat impact. B = May cause some adverse habitat impact. C = May cause significant adverse habitat impact. D = May cause the most adverse habitat impact. I = Insufficient Information – impact or effectiveness of the method could not be evaluated at this time. "-" = Not applicable for this oil type.

Response Method	*Gasoline Products*	*Diesel Products*	*Medium Oils*	*Heavy Oils*
Debris Removal	**-**	**A**	**A**	**A**
Low-Pressure, Cold-Water Flushing	**A**	**A**	**A**	**B**
Flooding	**A**	**A**	**A**	**C**
Natural Recovery	**A**	**A**	**B**	**B**
Sorbents	**-**	**A**	**A**	**B**
Vacuum	**-**	**B**	**B**	**B**
High-Pressure, Cold-Water Flushing	**C**	**B**	**B**	**B**
Nutrient Enrichment	**-**	**B**	**B**	**C**
Manual Oil Removal/Cleaning	**D**	**B**	**B**	**A**
Sediment Reworking	**D**	**B**	**B**	**B**
Shoreline Cleaning Agents	**-**	**-**	**B**	**B**
In-Situ Burning	**-**	**-**	**B**	**B**
Solidifiers	**-**	**-**	**B**	**-**
Low-Pressure, Hot-Water Flushing	**D**	**C**	**C**	**B**
Mechanical Oil Removal	**D**	**D**	**C**	**C**
High-Pressure, Hot-Water Flushing	**D**	**D**	**D**	**D**
Steam Cleaning	**-**	**D**	**D**	**D**
Chemical Shoreline Pretreatment	**-**	**I**	**I**	**I**
Natural Microbe Seeding	**-**	**I**	**I**	**I**

RESPONSE METHODS : GRAVEL HABITATS	
Least Adverse Habitat Impact	*Debris Removal* • Degree of oiling that warrants debris removal and disposal depends on use by humans and sensitive resources *Low-Pressure, Cold-Water Flushing* • Only effective when the oil is fluid and loosely adheres to the sediments • Usually used in conjunction with vacuum and sorbents • Use on heavy oils is likely to leave large amounts of residual oil in the environment *Flooding* • Only effective when the oil is fluid and adheres loosely to the sediments • Usually used with various flushing techniques • Use on heavy oils is likely to leave large amounts of residual oil in the environment *Natural Recovery* • Least impact for small spills, lighter oil types, remote areas, and eroding areas *Sorbents* • Overuse generates excess waste • Useful for recovering sheens, even for gasoline spills • Physical removal rates of heavy oils will be slow, so less oil will be mobilized for recovery by sorbents
Some Adverse Habitat Impact	*Vacuum* • Early use of vacuum on pooled, liquid oil can prevent deeper penetration *High-Pressure, Cold-Water Flushing* • High-pressure water jet is likely to flush finer sediments into nearshore submerged habitats • Very viscous oils will require extremely high pressure to mobilize them *Nutrient Enrichment* • Not applicable to gasoline spills because they rapidly evaporate • Concerns about nutrient overloading in poorly flushed areas or where nutrient toxicity, especially ammonia, might be significant • Potentially effective for lighter oils that leave thin residues; less effective for thick, weathered oil residues *Manual Oil Removal/Cleaning* • Gasoline tends to quickly evaporate; therefore manual cleanup causes habitat disruption, worker safety concerns, and generates waste with no benefits from removing oil • Minimizes sediment removal and problems of erosion and waste disposal • Deep penetration of oil in porous gravel reduces effectiveness *Sediment Reworking* • Used where gravel removal is not feasible because of erosion concerns • Sufficient exposure to waves is required to rework the sediments into their original profile and distribution • Gasoline tends to evaporate quickly; therefore sediment reworking causes habitat disruption, worker safety concerns, and generates waste with no benefits from removing oil *Shoreline Cleaning Agents* • May be only technique to remove viscous oils without removing sediment or using hot-water flushing • Individual products vary in their toxicity and ability to recover the treated oil *In-Situ Burning* • Can effectively remove pooled surface oil accumulations • May have to dig trenches to accumulate oil in pools • Lighter oils will not remain on the sediment surface • Concerns about air pollution, physical nature of the residue, and thermal impact on biota *Solidifiers* • Early use may prevent pooled oil from penetrating deeper • Not effective on heavy oils, which are too viscous to allow the product to mix into the oil • May be useful in recovering sheens when deployed as booms and pillows
Probable Adverse Habitat Impact	*Low-Pressure, Hot-Water Flushing* • May be needed to flush viscous or deeply penetrated oil • Any organisms present will be adversely affected by hot water *Mechanical Oil Removal* • Likely to remove large amounts of gravel with the oil • Foot and vehicular traffic on gravel could mix oil deeper into the sediments

RESPONSE METHODS : GRAVEL HABITATS	
Most Adverse Habitat Impact	*High-Pressure, Hot-Water Flushing* • High-pressure water jets are likely to flush oiled sediments into nearshore submerged habitats • Any organisms present will be adversely affected by hot water and high pressure *Steam Cleaning* • Highly intrusive technique; will kill any organisms present • Potential for released oil to penetrate deeper into the porous sediments
Insufficient Information	*Chemical Shoreline Pretreatment* • Need more information on available products, their effectiveness, and impact *Natural Microbe Seeding* • There is insufficient information on impact and effectiveness in freshwater habitats

9. VEGETATED SHORELINE HABITATS (ESI = 9A)	
Habitat Description	Vegetated shoreline habitats consist of the non-wetland vegetated banks that are common features of river systems and lakes. Bank slopes may be gentle or steep, and the vegetation consists of grasses, bushes, or trees common to the adjacent terrestrial habitats. The substrate is not water-saturated and can range from clay to gravel. The banks may flood seasonally and are exposed to relatively high-energy removal processes, at least periodically. Along undeveloped shorelines, there can be leafy litter and woody debris trapped among the vegetation. In developed areas, yards and gardens may abut the lake or river.
Sensitivity	Vegetated shoreline habitats are considered to have medium to high sensitivity to oil spills. They are not particularly important habitats for sensitive animals and plants, although many animals use vegetated banks for drinking, washing food, crossing bodies of water, and feeding. Bank plants oiled during a flood period could be susceptible, especially if the flood rapidly subsides, allowing oil to penetrate into bank sediments and to contact root systems. Small plants, particularly annuals, are likely to be most damaged. Stranded oil could remain in the habitat until another flood reaches the same level and provides a mechanism for natural flushing. On steep banks, the oil is likely to form a band, or multiple bands, at the waterline. On gentle banks, there is a greater potential for oil to accumulate in pools, penetrate the substrate, and coat large areas of vegetation, thus raising the issue of shoreline cleanup. In developed urban and suburban areas, human use and aesthetics would be the main reasons for cleanup.

Environmental impact from response methods for VEGETATED SHORELINE habitats (ESI = 9A).

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions: A = May cause the least adverse habitat impact. B = May cause some adverse habitat impact. C = May cause significant adverse habitat impact. D = May cause the most adverse habitat impact. I = Insufficient Information – impact or effectiveness of the method could not be evaluated at this time. “-“ = Not applicable for this oil type.

Response Method	*Gasoline Products*	*Diesel Products*	*Medium Oils*	*Heavy Oils*
Natural Recovery	**A**	**A**	**B**	**B**
Flooding	**B**	**A**	**A**	**B**
Low-Pressure, Cold-Water Flushing	**B**	**A**	**A**	**B**
Sorbents	**-**	**A**	**B**	**B**
Manual Oil Removal/Cleaning	**D**	**B**	**B**	**B**
Debris Removal	**-**	**B**	**B**	**B**
Vacuum	**-**	**B**	**B**	**B**
Vegetation Removal	**D**	**B**	**B**	**B**
Nutrient Enrichment	**-**	**B**	**B**	**B**
In-Situ Burning	**-**	**B**	**B**	**B**
High-Pressure, Cold-Water Flushing	**D**	**C**	**C**	**D**
Mechanical Oil Removal	**D**	**C**	**C**	**C**
Low-Pressure, Hot-Water Flushing	**D**	**D**	**D**	**D**
High-Pressure, Hot-Water Flushing	**D**	**D**	**D**	**D**
Sediment Reworking	**D**	**D**	**D**	**D**
Solidifiers	**-**	**D**	**D**	**-**
Chemical Shoreline Pretreatment	**-**	**I**	**I**	**I**
Shoreline Cleaners	**-**	**I**	**I**	**I**
Natural Microbe Seeding	**-**	**I**	**I**	**I**

<table>
<tr><th colspan="2">RESPONSE METHODS: VEGETATED SHORELINE HABITATS</th></tr>
<tr><td>Least Adverse Habitat Impact</td><td>Natural Recovery
• Low impact for small or moderate-size spills and lighter oils
• More impact for large spills of medium- or high-viscosity oils
Flooding
• Operationally difficult and marginally effective for steep banks
• Appropriate for gentle banks where persistent oil has pooled, assuming that the released oil can be directed towards recovery devices or sorbents
• Use on heavy oils is likely to leave large amounts of residual oil in the environment
• Use on gasoline spills may transport the oil to more sensitive habitats
Low-Pressure, Cold-Water Flushing
• Effective for washing oil stranded on the banks into the water for recovery
• Vegetation cover minimizes the potential for sediment erosion from flushing
• Use on heavy oils is likely to leave large amounts of residual oil in the environment
• Use on gasoline spills may transport the oil to more sensitive habitats</td></tr>
<tr><td>Some Adverse Habitat Impact</td><td>Sorbents
• Useful for recovering sheens, even for gasoline spills
• Physical removal rates of medium and heavy oils will be slow, so less oil will be mobilized for recovery by sorbents
• Overuse generates excess waste
Manual Oil Removal/Cleaning
• Some mixing of oil into the substrate and trampling of vegetation is unavoidable with foot traffic in oiled areas
• Gasoline tends to quickly evaporate; therefore habitat disruption, worker safety concerns, and waste generated by manual cleanup are not balanced by benefits in removing oil
Debris Removal
• Degree of oiling that warrants debris removal and disposal depends on use by humans and sensitive resources
• Minimal concerns where substrate is firm or work is conducted from boats
Vacuum
• Potential damage where substrate will not support vehicular traffic
• Most effective where access is good and substrate can support vehicles
• Only useful when oil is pooled
Vegetation Removal
• Usually not necessary to reduce oil impact on vegetation
• May be required in areas used by sensitive animals
Nutrient Enrichment
• Applicable where nutrients are a limiting factor for oil degradation
• More effective after gross oil removal is completed
• Not applicable to gasoline spills because they rapidly evaporate
In-Situ Burning
• May be the least physically damaging means of oil removal from the banks
• Least impact for grassy areas versus banks covered with trees and shrubs</td></tr>
<tr><td>Probable Adverse Habitat Impact</td><td>High-Pressure, Cold-Water Flushing
• High-pressure water spray will disturb plants and erode sediments
• Use on heavy oils is likely to leave large amounts of residual oil in the environment
• Use on gasoline spills may transport the oil to more sensitive habitats
Mechanical Oil Removal
• Excessive physical disruption likely from use of equipment</td></tr>
</table>

RESPONSE METHODS: VEGETATED SHORELINE HABITATS	
Most Adverse Habitat Impact	*Low-Pressure, Hot-Water Flushing* • Hot water could kill plants and potentially erode and degrade habitat *High-Pressure, Hot-Water Flushing* • Combination of high pressure and hot water poses high risk of sediment and vegetation loss *Sediment Reworking* • Will result in extensive habitat disruption *Solidifiers* • Not applicable to gasoline spills because they rapidly evaporate • Application of loose particulates may impede removal of oil mixed with, and adhered to, vegetation, litter, and debris • May be useful in recovering sheens when deployed as booms and pillows • Not effective on heavy oils, which are too viscous to allow the product to mix into the oil or penetrate netting or fabric encasing the loose particulates
Insufficient Information	*Chemical Shoreline Pretreatment* • There is insufficient information on impact and effectiveness in freshwater vegetation *Shoreline Cleaning Agents* • More information needed on available products, their effectiveness, and impact of use on vegetated bank habitats • Individual products vary in their toxicity and ability to recover the treated oil *Natural Microbe Seeding* • There is insufficient information on impact and effectiveness in freshwater vegetated shorelines

10. MUD HABITATS (ESI = 9B)	
Habitat Description	Mud habitats are characterized by a substrate composed predominantly of silt and clay sediments, although they may be mixed with varying amounts of sand or gravel. The sediments are mostly water saturated and have low bearing strength. In general, mud shorelines have a low gradient, although some steep banks also may consist of mud. The mud habitats generally are low energy and sheltered from wave action and high currents. Adjacent nearshore areas are usually shallow with muddy sediments. These fine-grained habitats often are associated with wetland. Bare or sparsely vegetated mud substrates are rare along Great Lake shorelines. However, they commonly occur along river floodplains and lake bottoms, where they can be exposed during seasonal low water levels.
Sensitivity	Mud habitats are highly sensitive to oil spills and subsequent response activities. Shoreline sediments are likely to be rich in organic matter and support an abundance of infauna. Muddy habitats are important feeding grounds for birds and rearing areas for fish. Oil will not penetrate muddy sediments because of their low permeability and high water content, except through decaying root and stem holes or animal burrows. There can be high Concentrations and pools of oil on the surface. Natural removal rates can be very slow, chronically exposing sensitive resources to the oil. The low bearing capacity of these shorelines means that response actions can easily leave long-lasting imprints, cause significant erosion, and mix the oil deeper into the sediments. When subsurface sediments are contaminated, oil will weather slowly and may persist for years. Response methods may be hampered by limited access, wide areas of shallow water, fringing vegetation, and soft substrate.

Environmental impact from response methods for MUD habitats (ESI = 9B).

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions: A = May cause the least adverse habitat impact. B = May cause some adverse habitat impact. C = May cause significant adverse habitat impact. D = May cause the most adverse habitat impact. I = Insufficient Information – impact or effectiveness of the method could not be evaluated at this time. "-" = Not applicable for this oil type.

Response Method	*Gasoline Products*	*Diesel Products*	*Medium Oils*	*Heavy Oils*
Natural Recovery	A	A	A	B
Flooding	B	A	A	A
Sorbents	B	A	A	B
Debris Removal	-	B	B	B
Vacuum	-	C	B	B
In-Situ Burning	C	C	C	C
Low-Pressure, Cold-Water Flushing	D	C	C	C
Manual Oil Removal/Cleaning	D	D	C	C
Low-Pressure, Hot-Water Flushing	D	D	C	C
Solidifiers	D	D	C	-
Mechanical Oil Removal	D	D	D	D
High-Pressure, Cold-Water Flushing	D	D	D	D
High-Pressure, Hot-Water Flushing	D	D	D	D
Sediment Reworking	D	D	D	D
Shoreline Cleaning Agents	-	D	D	D
Natural Microbe Seeding	-	I	I	I
Nutrient Enrichment	-	I	I	I
Chemical Shoreline Pretreatment	I	I	I	I

RESPONSE METHODS: MUD HABITATS	
Least Adverse Habitat Impact	*Natural Recovery* • Least impact for small spills and lighter oils, to prevent disruptions associated with cleanup efforts • For large spills or heavy oils, expect long-term persistence in low-energy settings *Flooding* • Effective only for fresh, fluid oils • Local topography may limit the ability to control where the water and released oil flow and effectiveness of recovery • Use on gasoline spills may transport the oil to more sensitive habitats *Sorbents* • Useful as long as the oil is mobilized and recovered by the sorbent • Overuse generates excess waste • Careful placement and recovery is necessary to minimize substrate disruption
Some Adverse Habitat Impact	*Debris Removal* • Degree of oiling that warrants debris removal and disposal depends on use by sensitive resources • Extensive disruption of soft substrate likely *Vacuum* • Not applicable to gasoline spills because of safety concerns • Use to remove oil pooled on the surface • Avoid digging trenches to collect oil because they can introduce oil deeper into the sediment • Disruption of soft substrates can be limited by placing boards on the surface and controlling access routes
Probable Adverse Habitat Impact	*In-Situ Burning* • Heat may impact biological productivity of habitat, especially where there is no standing water to act as a heat sink on top of the mud *Low-Pressure, Cold-Water Flushing* • Mud is readily suspended if substrate is not firm • Not effective for higher-viscosity oils that will not move with low pressure • Local topography may limit the ability to control where the water and released oil flow and effectiveness of recovery • Use on gasoline spills may transport the oil to more sensitive habitats *Manual Oil Removal/Cleaning* • Use where persistent oil occurs in moderate to heavy amounts, or where sensitive resources must be protected • Response crews may trample soft substrates, mix oil deeper into the sediments, and contaminate clean areas *Low-Pressure, Hot-Water Flushing* • Physical and thermal impacts to habitat likely
Most Adverse Habitat Impact	*Solidifiers* • High likelihood of disruption and mixing of oil deeper into the substrate during application and retrieval • Not effective on heavy oils, which are too viscous to allow the product to mix into the oil *Mechanical Oil Removal* • Soft substrate will not support vehicular traffic • Will probably cause extensive physical habitat disruption *High-Pressure, Cold-Water Flushing and High-Pressure, Hot-Water Flushing* • High-pressure water will cause extensive sediment suspension and erosion • Potential for burial of oiled sediments and transport of oil to adjacent areas *Sediment Reworking* • Will extensively disrupt physical habitat • Increases oil penetration, burial, and persistence *Shoreline Cleaning Agents* • Current products are designed for use with high-pressure flushing; since used with flushing, water pressure needs to be considered • Individual products vary in their toxicity and ability to recover the treated oil

RESPONSE METHODS: MUD HABITATS	
Insufficient Information	*Natural Microbe Seeding and Nutrient Enrichment* • Not applicable to gasoline spills because they rapidly evaporate • There is insufficient information on impact and effectiveness in mud habitats *Chemical Shoreline Pretreatment* • There is insufficient information about direct toxicity of the products, disturbances resulting from application and retrieval, effectiveness, and net benefit

11. WETLAND HABITATS (ESI = 10A, 10B)	
Habitat Description	Wetlands are characterized by water, unique soils that differ from adjacent upland areas, and vegetation adapted to wet conditions. Wetlands include a range of habitats such as marshes, bogs, bottomland hardwood forests, fens, playas, prairie potholes, and swamps. Substrate, vegetation, hydrology, seasonality, and biological use of inland wetlands are highly variable, making characterization difficult. The surfaces of wetlands usually have a low gradient and vegetated areas are typically at or under the water level. There can be distinct channels or drainages with flowing water, except at the exposed outer fringe; however, natural physical processes are minimal. Water levels may vary seasonally, and the wetland may be simply a zone of water-saturated soils during the dry season.
Sensitivity	Wetlands are highly sensitive to oil spills. The biological diversity in these habitats is significant and they provide critical habitat for many types of animals and plants. Oil spills affect both the habitat (vegetation and sediments) and the organisms that directly and indirectly rely on the habitat. Surprisingly little is known about oil impact on freshwater plants, although there are likely differences between robust perennials with substantial underground systems and cycles of winter die-back, and annuals that lack underground nutrient reserves. Detritus-based food webs are fundamentally important in wetlands; oil could possibly affect these by slowing decomposition rates of plant material. Wetlands support populations of fish, amphibians, reptiles, birds, and mammals, with many species reliant upon wetlands for their reproduction and early life stages when they are most sensitive to oil. Many endangered animals and plants occur only in wetlands, and spills in such areas would be of particular conservation concern. Migratory waterbirds depend heavily on wetlands as summer breeding locations, migration stopovers, and winter habitats. The threat of direct oiling of animals using the wetland often drives efforts to remove the oil. If oil and/or cleanup efforts causes a loss of the more sensitive plants or modifies the ecosystem structure, then feeding and breeding of dependent wildlife may be affected.

Environmental impact from response methods for WETLAND habitats (ESI = 10A, 10B).				
The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions: A = May cause the least adverse habitat impact. B = May cause some adverse habitat impact. C = May cause significant adverse habitat impact. D = May cause the most adverse habitat impact. I = Insufficient Information – impact or effectiveness of the method could not be evaluated at this time. "-" = Not applicable for this oil type.				
Response Method	*Gasoline Products*	*Diesel Products*	*Medium Oils*	*Heavy Oils*
Natural Recovery	**A**	**A**	**A**	**B**
Sorbents	**C**	**A**	**A**	**A**
Flooding	**B**	**A**	**A**	**B**
Low-Pressure, Cold-Water Flushing	**B**	**A**	**A**	**B**
In-Situ Burning	**B**	**B**	**B**	**B**
Vacuum	**-**	**B**	**B**	**B**
Debris Removal	**-**	**B**	**B**	**B**
Vegetation Removal	**D**	**C**	**C**	**C**
Manual Oil Removal/Cleaning	**D**	**D**	**C**	**C**
High-Pressure, Cold-Water Flushing	**D**	**D**	**D**	**D**
Low-Pressure, Hot-Water Flushing	**D**	**D**	**D**	**D**
High-Pressure, Hot-Water Flushing	**D**	**D**	**D**	**D**
Mechanical Oil Removal	**D**	**D**	**D**	**D**
Sediment Reworking	**D**	**D**	**D**	**D**
Solidifiers	**D**	**D**	**D**	**-**
Shoreline Cleaning Agents	**-**	**I**	**I**	**I**
Nutrient Enrichment	**-**	**I**	**I**	**I**
Natural Microbe Seeding	**-**	**I**	**I**	**I**
Chemical Shoreline Pretreatment	**-**	**I**	**I**	**I**

RESPONSE METHODS: WETLAND HABITATS	
Least Adverse Habitat Impact	*Natural Recovery* • Least impact for small to moderate spills and lighter oils; avoids damage often associated with cleanup activities • Some cleanup may be warranted where large numbers of animals are likely to become oiled during wetland use *Sorbents* • Care is necessary during placement and recovery to minimize disturbance of substrate and vegetation • Overuse generates excess waste *Flooding* • Erosion of substrate and vegetation may be a problem • Can be used selectively to remove localized heavy oiling • Can be difficult to direct water and oil flow towards recovery devices • Use on heavy oils is likely to leave large amounts of residual oil in the environment • Use on gasoline spills may transport the oil to more sensitive habitats *Low-Pressure, Cold-Water Flushing* • If water pressures are too high, the substrate and vegetation may be disturbed • Use on heavy oils is likely to leave large amounts of residual oil in the environment • Use on gasoline spills may transport the oil to more sensitive habitats
Some Adverse Habitat Impact	*In-Situ Burning* • May be one of the least physically damaging means of heavy oil removal • Presence of a water layer on marsh surface can protect roots • Time of year (vegetation growth stage) is important consideration • May be appropriate for gasoline spills trapped in ice *Vacuum* • Can be effective in removal of pooled oil from the marsh surface • Trampling of vegetation and substrate can be limited by placing boards on the surface and limiting traffic *Debris Removal* • The removal of heavily oiled and mobile debris may reduce the tracking of oil off-site and contamination of wildlife
Probable Adverse Habitat Impact	*Vegetation Removal* • Used to prevent oiling of sensitive animals using the wetland • Most appropriate for oils that form a thick, sticky coating on the vegetation, such as medium and heavy oils • May delay recovery of the vegetation due to both oil impact and physical destruction by cleanup crews • Trampling of vegetation may be reduced by controlling access routes, using boards placed on surface, or conducting operations from boats *Manual Oil Removal/Cleaning* • Used where persistent oil occurs in heavy amounts and where sensitive resources using the wetlands are likely to be oiled • Response crews may trample roots and mix oil deeper into the sediments

RESPONSE METHODS: WETLAND HABITATS	
Most Adverse Habitat Impact	*High-Pressure, Cold-Water Flushing* • High-pressure spray will disrupt sediments, root systems, and animals *Low-Pressure, Hot-Water Flushing and High-Pressure, Hot-Water Flushing* • Hot water will likely kill the vegetation *Mechanical Oil Removal* • Using vehicles in soft substrate will probably cause extensive physical disruption • Can completely alter the marsh substrate, hydrology, and vegetation patterns for many years • Use in heavily oiled wetlands when all other techniques have failed and there is an overriding reason for oil removal *Sediment Reworking* • No benefit from mixing oil deeper into fine-grained and organic soils *Solidifiers* • Not applicable to gasoline spills because they rapidly evaporate • Use likely to increase adherence to vegetation and slow weathering/removal rates of residual oil • Not effective on heavy oils, which are too viscous to allow the product to mix into the oil
Insufficient Information	*Shoreline Cleaning Agents* • More information needed on available products, their effectiveness, and impact of use on vegetated bank habitats • Individual products vary in their toxicity and recoverability of the treated oil *Nutrient Enrichment and Natural Microbe Seeding* • Not applicable to gasoline spills because they rapidly evaporate • Concerns include eutrophication and acute toxicity, particularly from ammonia, because of shallow waters and low mixing rates • There is insufficient information on impact and effectiveness in wetlands *Chemical Shoreline Pretreatment* • There is insufficient information about product toxicity, disturbances resulting from application and retrieval, effectiveness, and net benefit

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